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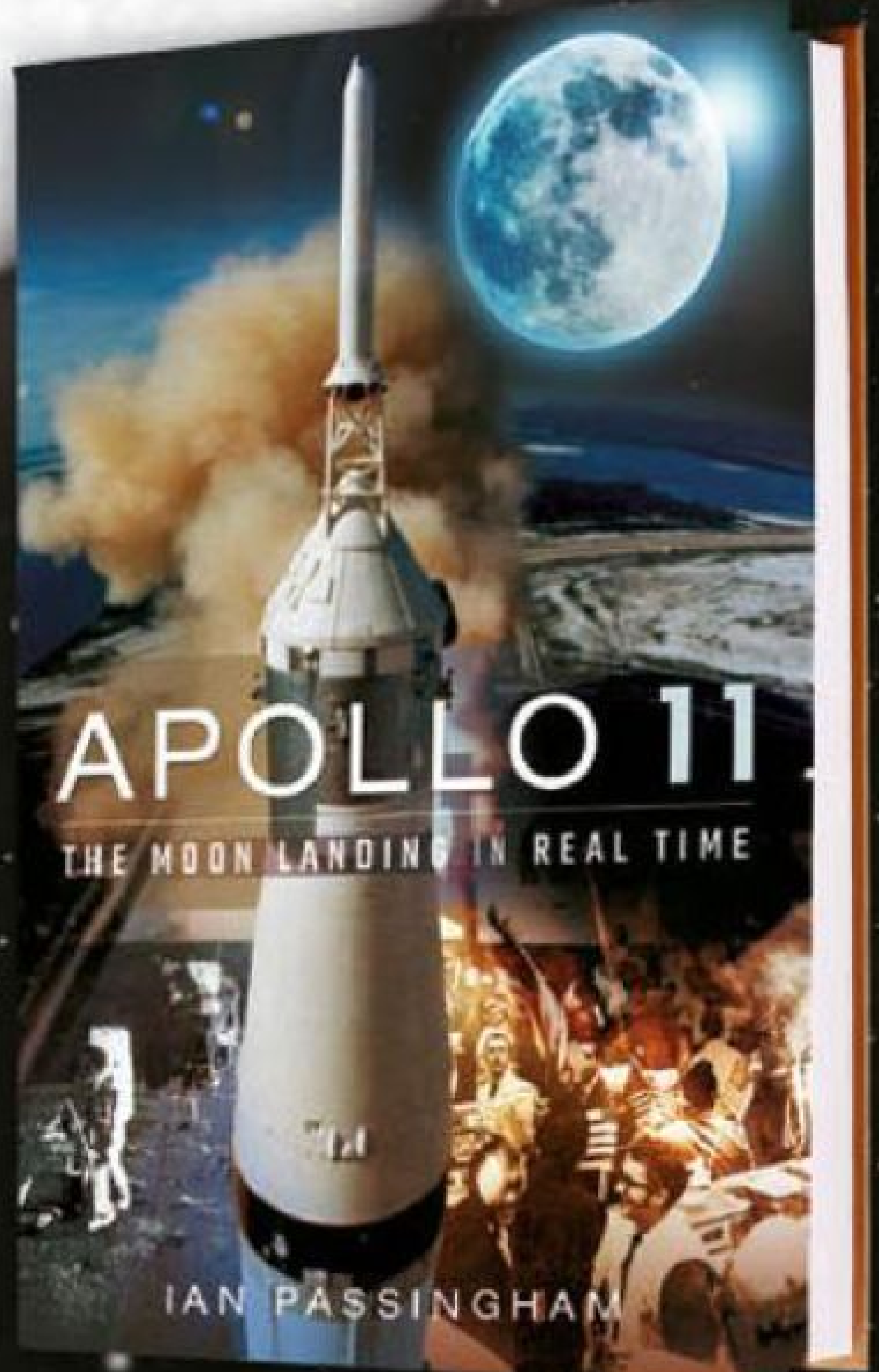

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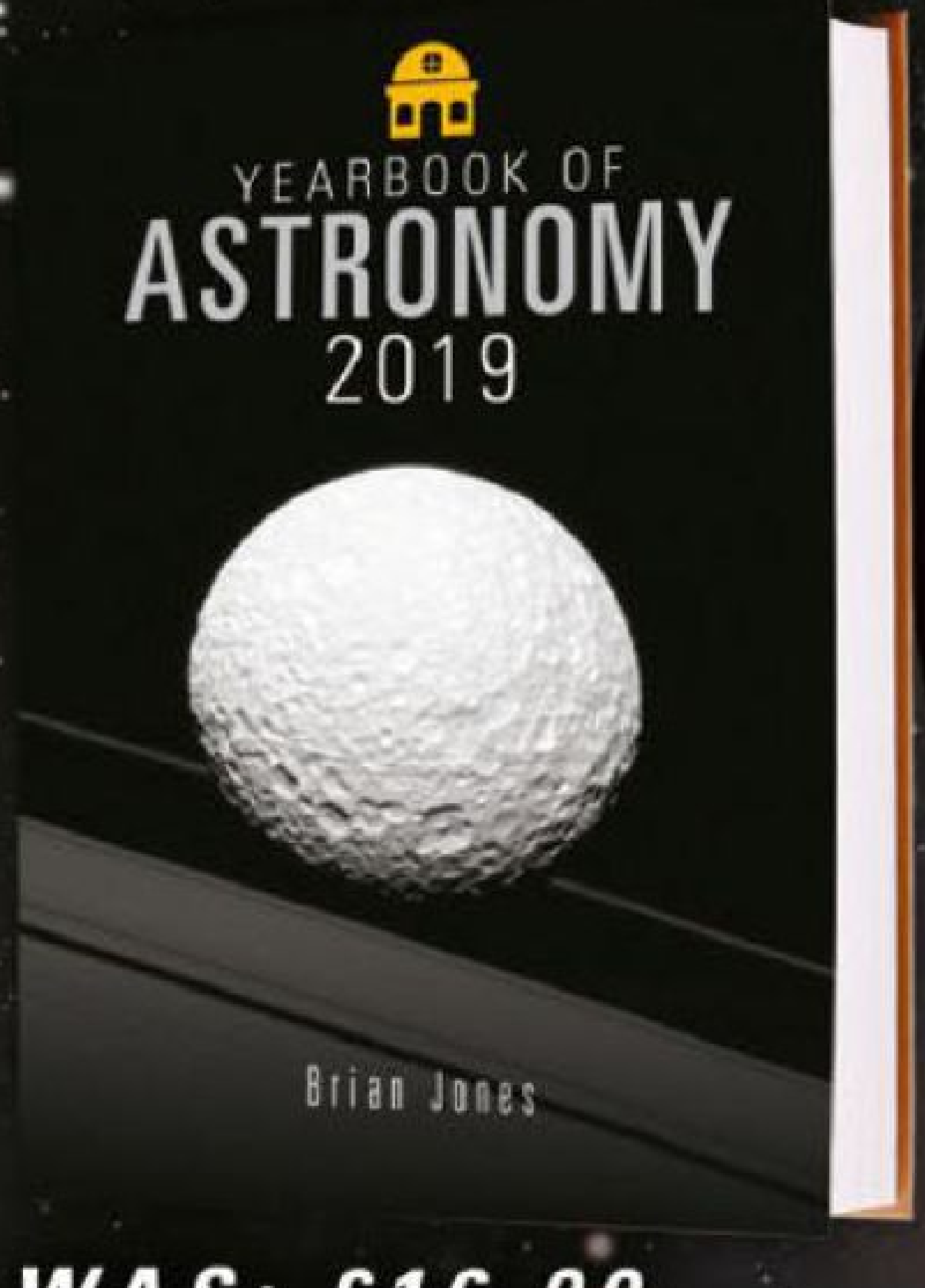

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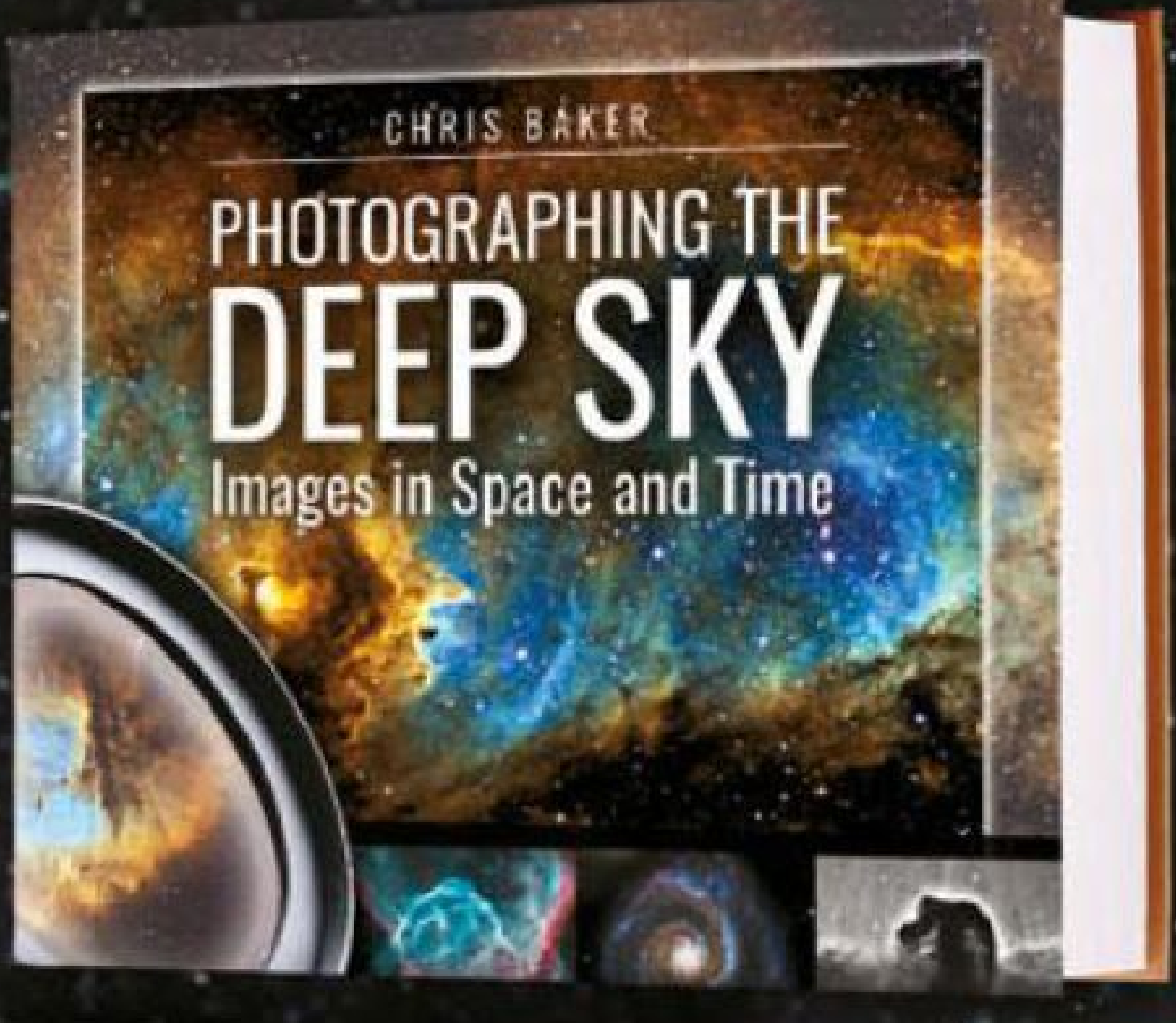

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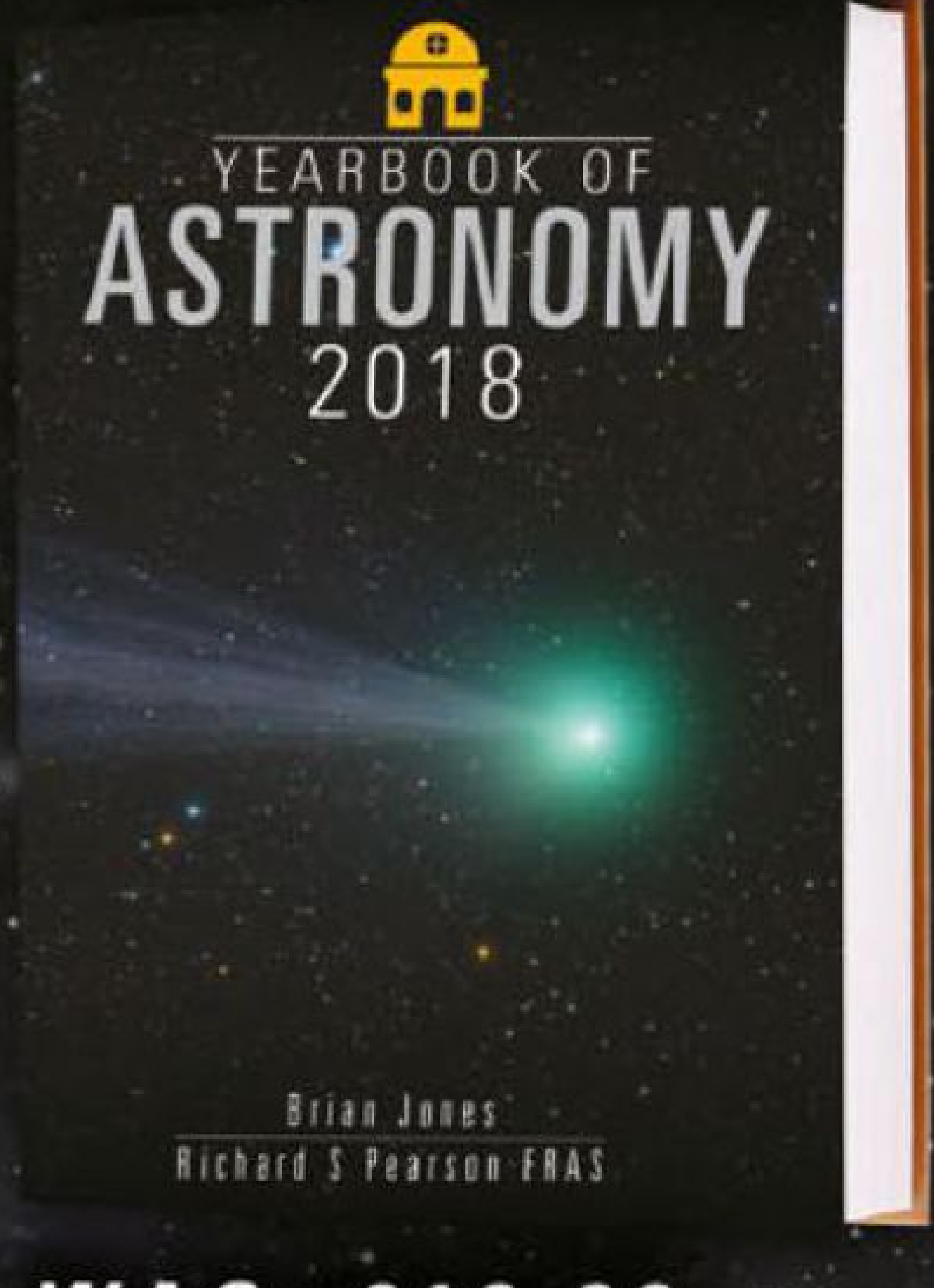

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It's been 50 years since astronauts first walked on the Moon

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Welcome

This issue marks 50 years since humankind first stepped foot on the lunar surface. Apollo 11 was a mission like no other, carrying three men into space, to make history.

Over on page 16, we've begun our special anniversary issue where we chat exclusively to Apollo Lunar Module Pilot Buzz Aldrin, Command Module Pilot Michael Collins, NASA flight director Gene Kranz and many more about what really happened the day spacesuit boot touched lunar soil for the very first time. And that's not all, you - our readers - reveal your memories of the mission, while Neil Armstrong's biographer James Hansen gives us an insight into who the Apollo 11 Commander really was, crushing the rumours that surround the astronaut's personality and life.

Don't forget to take the time to observe the lunar surface this month - this issue we provide a full guide to not only help you get the very best views of the Apollo 11 landing site, but the missions that followed several years later. Plus, if you're a keen collector of Moon landing memorabilia, we've put together the ultimate guide to Apollo 11 merchandise, featuring the likes of LEGO, Fisher Space Pens, Omega and many, many more.

If you're a subscriber or a resident of the UK, we hope you enjoy your two free gifts this month - *Apollo 11: The Inside Story,* courtesy of Icon Books, plus two Haynes Manual posters. See you next month!

Gemma Lavender
Editor-in-Chief

Our contributors include...

Andrew May
Space science writer
Has one of the greatest minds of our time put an end to the multiverse theory? Andrew reveals the results of Stephen Hawking's final paper explains why

Abigail Beall
Space science writer
What's beyond what we define as deep space? Speaking to the scientists behind Hubble and James Webb, Abigail has the tantalising details

Stuart Atkinson
Astronomer
Stuart continues his summer night sky tour this issue, revealing some treasures you can observe in the constellations of Cygnus and the surrounding sky

Lee Cavendish
Staff Writer
Lee chats to physicist Carlo Rovelli about the complications of space and time. Do we really understand the latter as much as we originally thought?

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LAUNCH PAD

YOUR FIRST CONTACT WITH THE UNIVERSE

06 Black holes might not merely be harbingers of destruction, two new exoplanets have been found nearby and Spitzer readies to retire in 2020

FEATURES

16 **Secrets of Apollo 11**
We reveal the classified information hidden even from the crew themselves

24 **Interview Carlo Rovelli**
The Italian theoretical physicist speaks to **All About Space** about the enigma that is time

28 **Where do black holes lead?**
If you could journey through the cosmos' most monstrous objects, what tales - if any - would you be able to tell?

38 **Planet Profile Pluto**
The dwarf planet in the realms of the Kuiper Belt is not just a barren ball of rock and ice

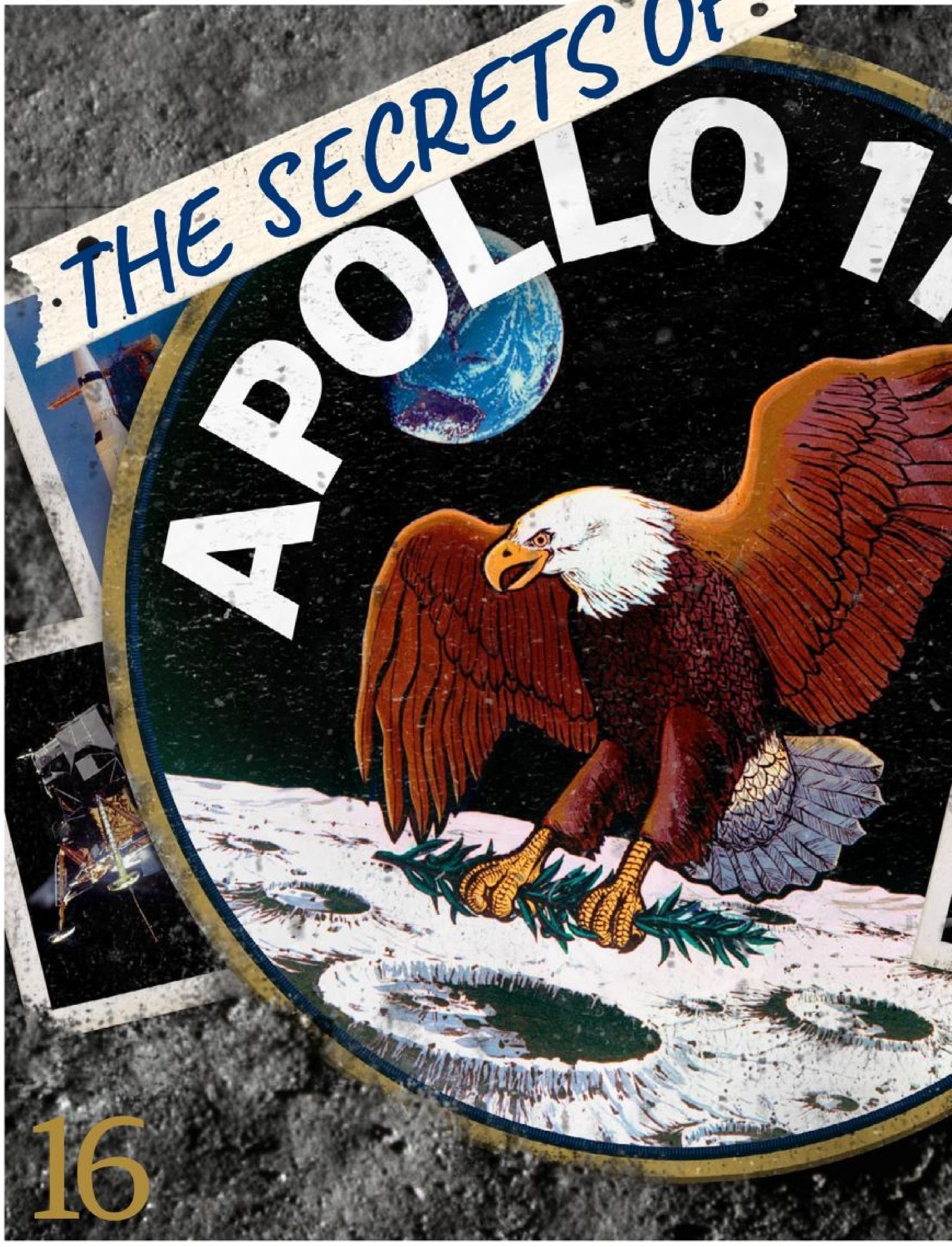
42 **Ask Space**
Your questions answered by our experts

52 **End of the multiverse**
A posthumous paper by Stephen Hawking cuts cosmology's controversial hypothesis down to size

58 **Focus on Europa salt**
Common table salt has been identified on Jupiter's moon

62 **Future Tech Lunar landings**
NASA has funded a host of small businesses developing new technology that can make landing on the Moon safer and more reliable than ever

64 **Beyond deep space**
How technology is helping us peer to the edges of the observable universe



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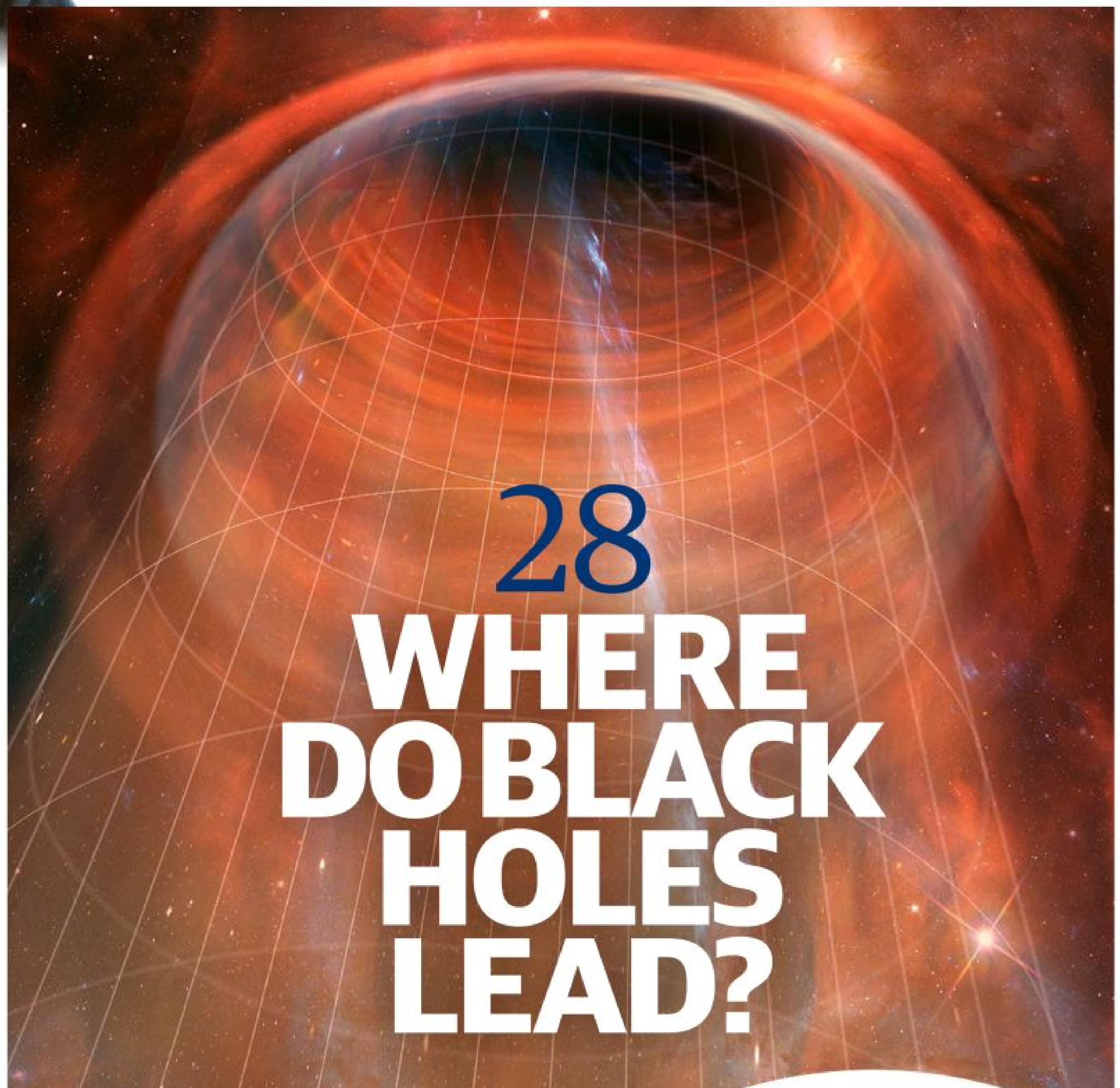
TURN TO PAGE 36
FOR DETAILS

"The idea of a single time that passes at the same speed is completely wrong"

60 Carlo Rovelli,, Centre de Physique Théorique de Luminy at Aix-Marseille University



28

WHERE DO BLACK HOLES LEAD?

78

APOLLO LANDING SITES

END OF THE MULTIVERSE

52

STARGAZER

Your complete guide to the night sky

70 **What's in the sky?**
The shortest nights are now behind us, with new sights to look forward to

74 **Planets on display**
Saturn takes the spotlight, while Mercury, Venus and Mars are challenging targets

76 **Moon tour**
To the south of Plato are mountains worth exploring with a telescope

77 **Naked eye & binocular targets**
The Cygnus star cloud reveals millions of tiny stars

78 **Observe the Apollo landing sites**
Find the exact spots where history was made

84 **Deep sky challenge**
Glittering star clusters, a dead star's corpse and a beautiful double star to split

86 **The Northern Hemisphere**
A gaggle of galaxies, clusters and nebulae grace the skies

88 **Astrophotos of the month**
The best of our readers' astrophotography

90 **Telescope review**
Is the Meade Polaris 114 EQ the right 'scope for you?

94 **Apollo gift guide**
Our pick of the best commemorative Apollo 11 products

92

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The red face of El Salvador

Welcome to the smallest and most densely populated country in Central America – El Salvador. This false-colour image was captured by the European Space Agency's Copernicus Sentinel-2 spacecraft. It's shown largely in red to give a better idea of the vegetation within the region.

This image shows many recognisable areas of El Salvador, including Lake Güija (top left), the Cerro Verde National Park (lower left) and the volcano Izalco (below Cerro Verde). To the right of that is Coatepeque Caldera.

© ESA

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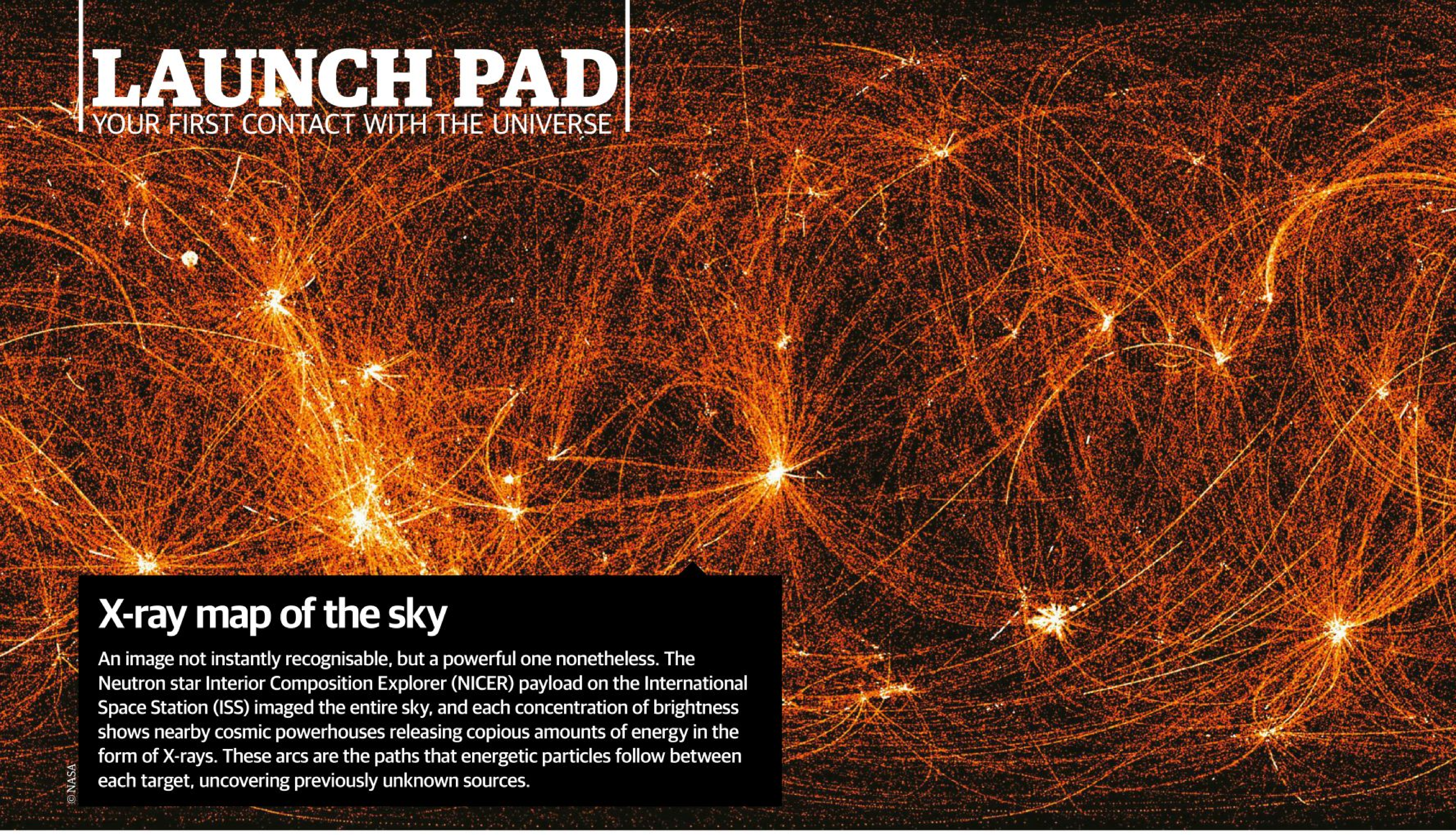
YOUR FIRST CONTACT WITH THE UNIVERSE



X-ray map of the sky

An image not instantly recognisable, but a powerful one nonetheless. The Neutron star Interior Composition Explorer (NICER) payload on the International Space Station (ISS) imaged the entire sky, and each concentration of brightness shows nearby cosmic powerhouses releasing copious amounts of energy in the form of X-rays. These arcs are the paths that energetic particles follow between each target, uncovering previously unknown sources.

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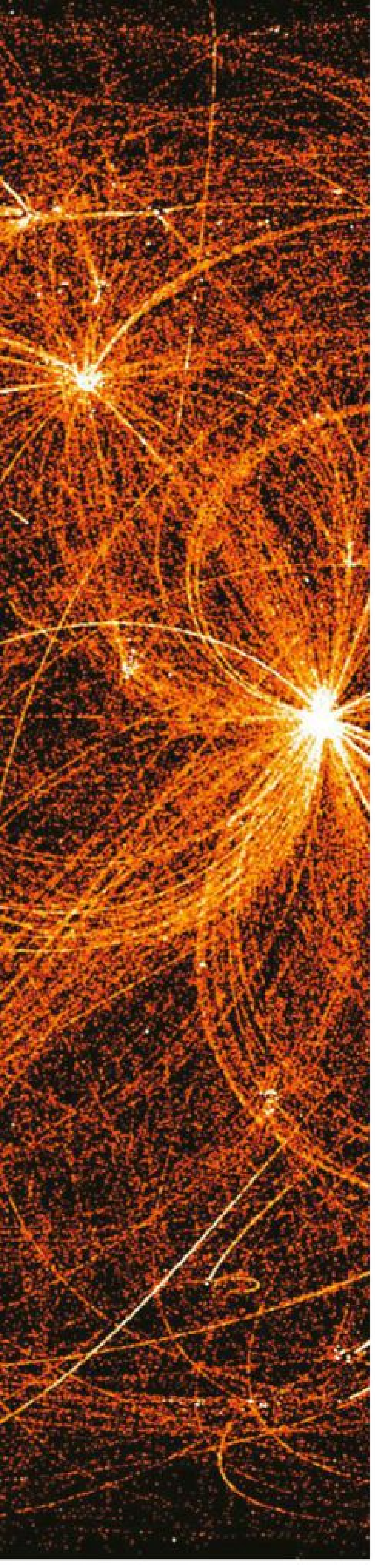

Hidden Figures Way unveiling

On 12 June 2019, NASA administrator Jim Bridenstine, United States senator Ted Cruz, D.C. Council chairman Phil Mendelson and Margot Lee Shetterly, author of the book *Hidden Figures*, unveiled the fabulous new 'Hidden Figures Way' street sign in a ceremony.

This street sign is a great way to commemorate the African-American women that were essential to the early days of spaceflight. Cruz made an appropriate statement, saying it's "not just a story of individuals but it's also a story of, and acknowledges, the racism in this country and how we still struggle to deal with that and to overcome it".

Galaxies and asteroids collide

The Hubble Space Telescope created a beautiful canvas of distant galaxies, lying millions and billions of light years away. However, there was an unusual photobomb – the appearance of several nearby asteroids skimming past. These streaks were created as several asteroids just tens to hundreds of millions of kilometres away from Earth glided past the field of view during multiple exposures. With 20 asteroid trails shown, a team of astronomers used this image to identify and characterise these objects, getting a better understanding of the nearby objects that serendipitously came to their attention.

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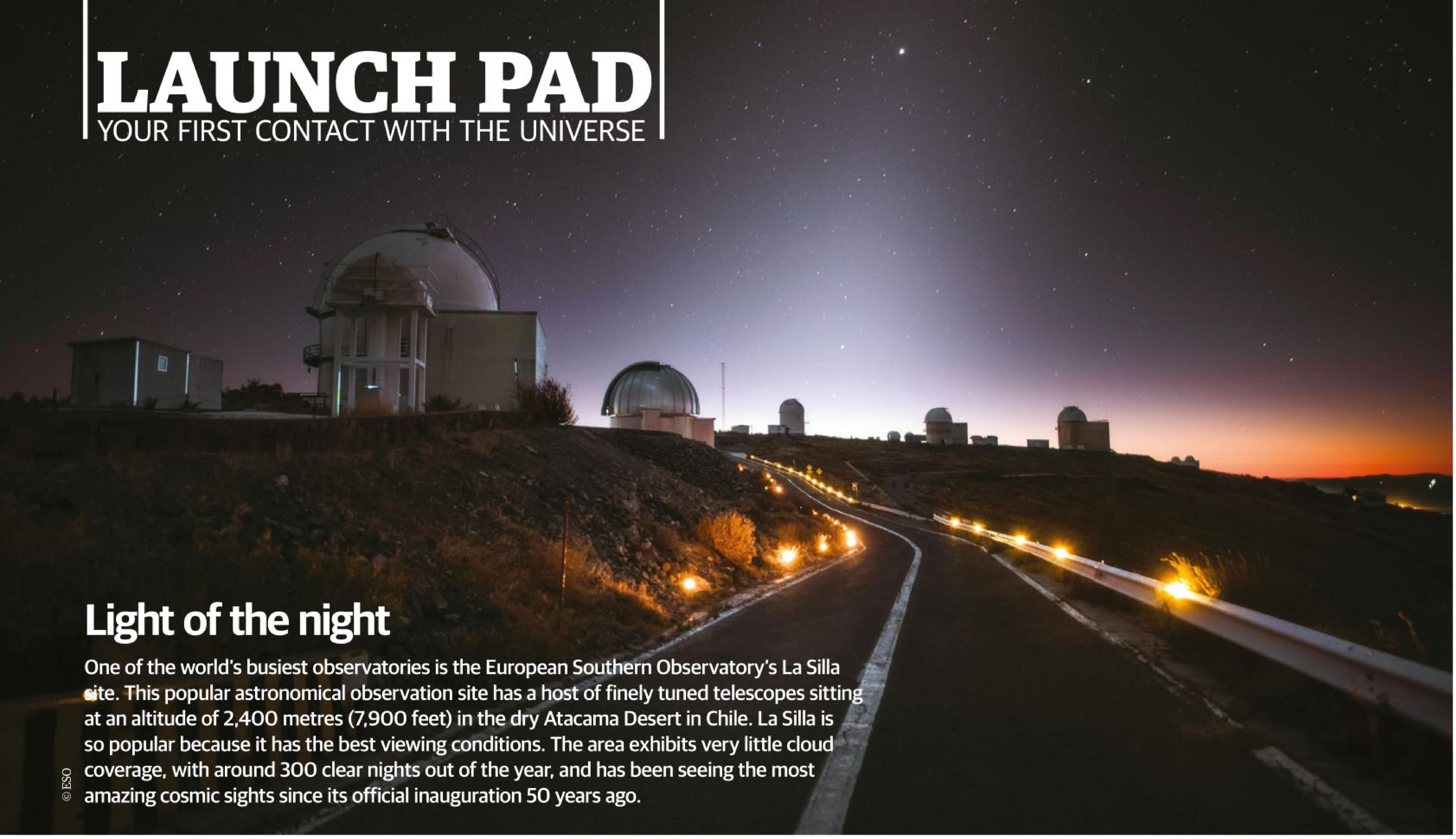

Light of the night

One of the world's busiest observatories is the European Southern Observatory's La Silla site. This popular astronomical observation site has a host of finely tuned telescopes sitting at an altitude of 2,400 metres (7,900 feet) in the dry Atacama Desert in Chile. La Silla is so popular because it has the best viewing conditions. The area exhibits very little cloud coverage, with around 300 clear nights out of the year, and has been seeing the most amazing cosmic sights since its official inauguration 50 years ago.

© ESO

Getting a taste for space

The Mars 2020 rover will soon jettison from Earth, travelling onward to the Red Planet. However, engineers have to be diligent in their testing in making sure the rover can survive this journey.

This shows NASA's Mars 2020 spacecraft assembled and placed in the acoustic and thermal vacuum (TVAC) testing chamber at the Jet Propulsion Laboratory in Pasadena, California, United States. This chamber is the best analogue engineers have in order to test the vibrations and temperatures endured in such a powerful liftoff without actually going to space.

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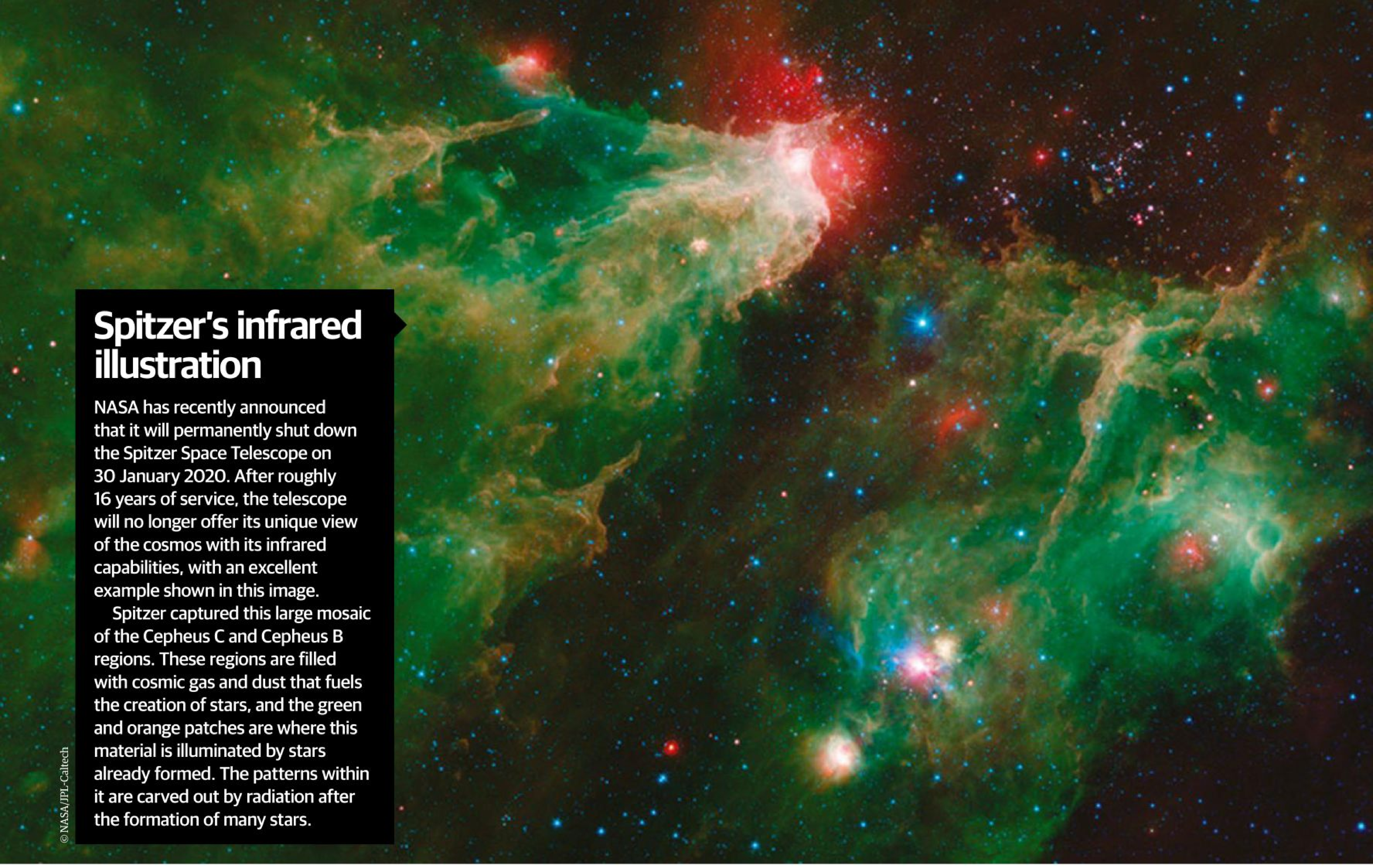

Spitzer's infrared illustration

NASA has recently announced that it will permanently shut down the Spitzer Space Telescope on 30 January 2020. After roughly 16 years of service, the telescope will no longer offer its unique view of the cosmos with its infrared capabilities, with an excellent example shown in this image.

Spitzer captured this large mosaic of the Cepheus C and Cepheus B regions. These regions are filled with cosmic gas and dust that fuels the creation of stars, and the green and orange patches are where this material is illuminated by stars already formed. The patterns within it are carved out by radiation after the formation of many stars.

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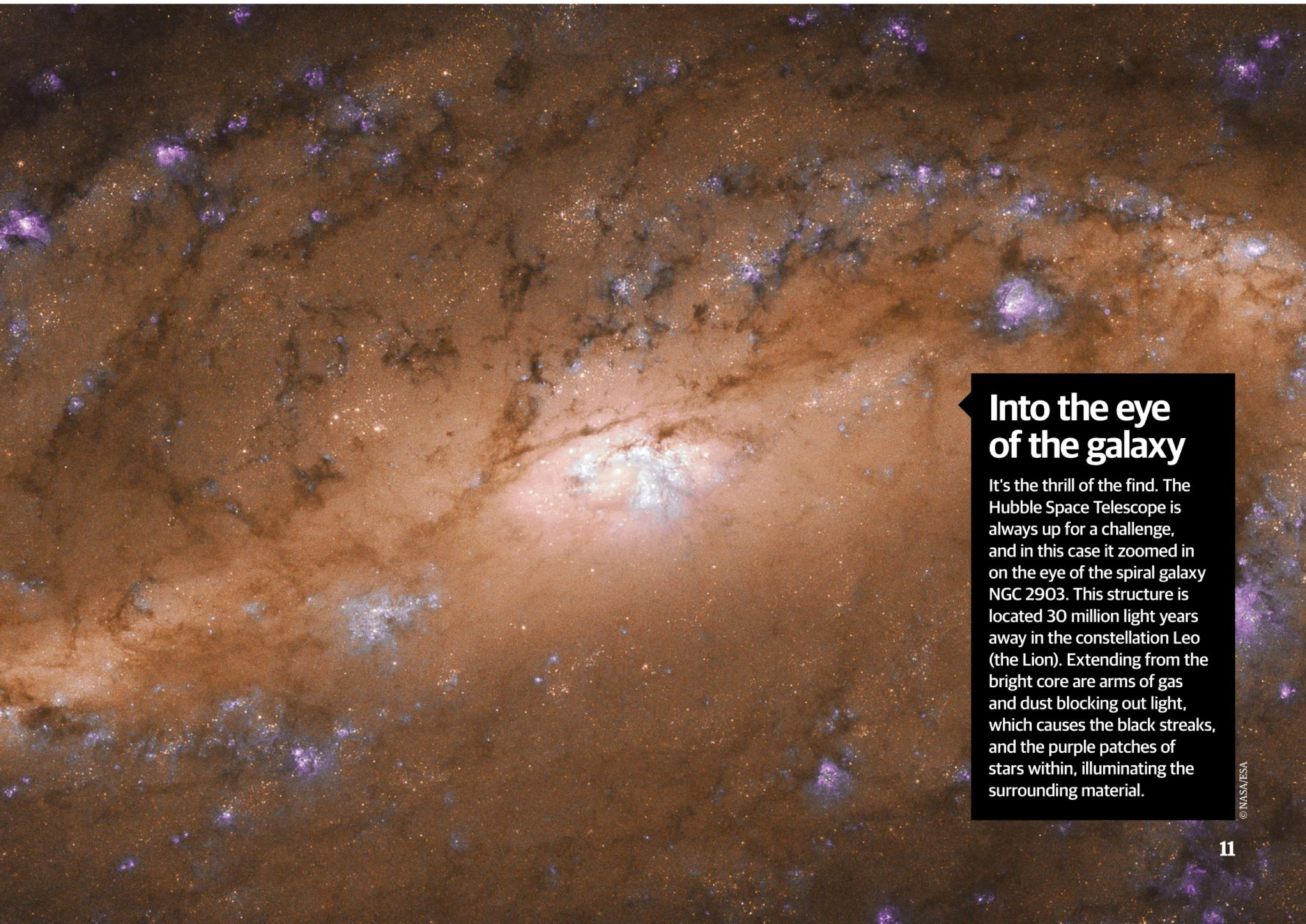


Into the eye of the galaxy

It's the thrill of the find. The Hubble Space Telescope is always up for a challenge, and in this case it zoomed in on the eye of the spiral galaxy NGC 2903. This structure is located 30 million light years away in the constellation Leo (the Lion). Extending from the bright core are arms of gas and dust blocking out light, which causes the black streaks, and the purple patches of stars within, illuminating the surrounding material.

© NASA/ESA

Voracious black holes could feed alien life on rogue worlds

Words by **Mara Johnson-Groh**

Black holes are engines of destruction on a cosmic scale, but they may also be the bringers of life. New research on supermassive black holes suggests that the radiation they emit during feeding frenzies can create biomolecular building blocks and even power photosynthesis. The upshot? Far more worlds roaming the Milky Way and beyond could be suitable for life, the researchers speculated.

For their new study scientists created computer models to look at the radiating discs of gas and dust called active galactic nuclei, or AGN, that swirl around supermassive black holes. Some of the brightest objects in the universe, AGN form as a black hole's gravity binds matter. As that matter swirls around a black hole, it releases incredible amounts of light and radiation.

Since the early 1980s scientists have suspected that this radiation would create a dead zone around an AGN. Some researchers even proposed that such an AGN could explain why we haven't seen any complex extraterrestrial life towards the centre of the Milky Way. Our galaxy has a monstrous black hole at its centre, called Sagittarius A*. Previous studies have found that within 3,200 light years of a Sagittarius A*-sized AGN, X-rays and ultraviolet light could strip the atmospheres from Earth-like planets.

The researchers' models suggest that worlds with atmospheres that are thicker than Earth's or those far enough away from an AGN to retain their atmospheres might still stand a chance of hosting life. At certain distances there exists a galactic Goldilocks zone that gets just the right amount of ultraviolet radiation.

At this level of radiation the atmosphere wouldn't be stripped away, but the radiation could break apart molecules, creating compounds that are necessary for building proteins, lipids and DNA – the cornerstones to life, at least as we know it. For a black hole the size of Sagittarius A*, the Goldilocks region would extend approximately 140 light years from the black hole's centre.

The scientists also looked at the effects of the radiation on photosynthesis, the process by which most plants utilise the Sun's energy to create sugars, and AGN emit enormous amounts of that key ingredient – light.

This would be particularly important for plants on free-floating planets, which have no nearby host star to provide a light source. Astronomers have estimated there could be around 1 billion such rogue planets drifting in the Goldilocks zone of a Milky Way-like galaxy, according to Manasvi Lingam, lead author on the study and an astronomer at Harvard University.

Calculating the area over which AGN could power photosynthesis, the scientists found that large portions of galaxies could have AGN-powered photosynthesis. For a galaxy similar to our own, this region would extend around 1,100 light years out from the centre of the galaxy. In small, dense galaxies called ultra-compact dwarfs, more than half of the galaxy could reside in that photosynthetic zone.

© ESA/NASA

Mysterious glow warms Uranus' rings

Words by **Elizabeth Howell**

Some sort of a heat wave warms the rings of Uranus, even though the planet orbits far away from the Sun.

New heat images of the planet, obtained by two telescopes in Chile, reveal the temperature of the rings for the first time: -195 degrees Celsius (-320 degrees Fahrenheit), or the boiling temperature of liquid nitrogen.

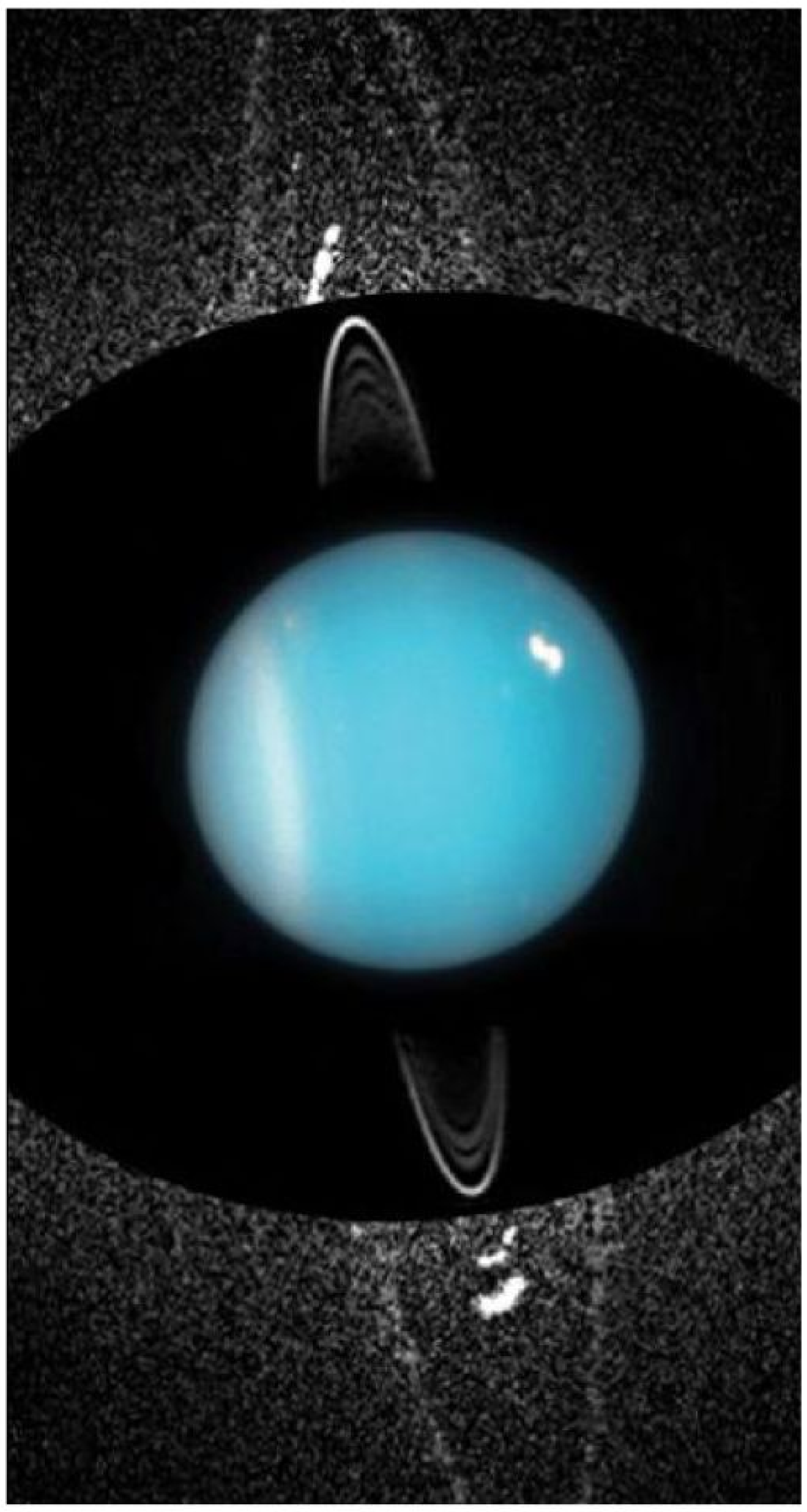
While that sounds cold by Earthly standards, consider that most of space is much colder, approaching a temperature at which atoms stop moving. This point is called absolute zero, which is roughly -273 degrees Celsius (-460 degrees Fahrenheit).

And Uranus itself is located pretty far out in the Solar System, where the planet receives only a fraction of the heat from the Sun that the Earth receives. The ice giant orbits our star at an average distance of 19 Astronomical Units (AU), with each AU equivalent to the average distance from the Earth to the Sun, or 150 million kilometres (93 million miles).

The scientists who captured the new images said they aren't sure what's causing the relative warmth. But the weird temperature proves that the brightest and densest ring at Uranus, also known as the epsilon ring, is very different from other ring systems in our Solar System. "The small end is missing in the main rings of Uranus. The brightest ring, epsilon, is composed of golf-ball-sized and larger rocks," explained Imke de Pater, an astronomer at the University of California, Berkeley.

The epsilon ring also differs from rings observed at the other giant planets. Jupiter's rings are made of particles that are roughly a thousandth of a millimetre in diameter each, while Neptune's rings are made up almost entirely of dust. The epsilon ring doesn't even look like the main rings of Uranus – huge tracts of dust lie in between them.

"We already know that the epsilon ring is a bit weird, because we don't see the smaller stuff," lead author and graduate student Edward Molter, who is also at the University of California, Berkeley, said in the same statement. "Something has been sweeping the smaller stuff out, or it's all glomming together. We just don't know. This is a step towards understanding [the rings'] composition and whether all of the rings came from the same source material or are different for each ring."



Uranus' rings differ greatly from those on neighbouring ringed planets

© ESA/NASA

Proximity to black hole radiation can affect the atmospheres of planets

‘Atlas of Space’ smashes textbook view of the Solar System

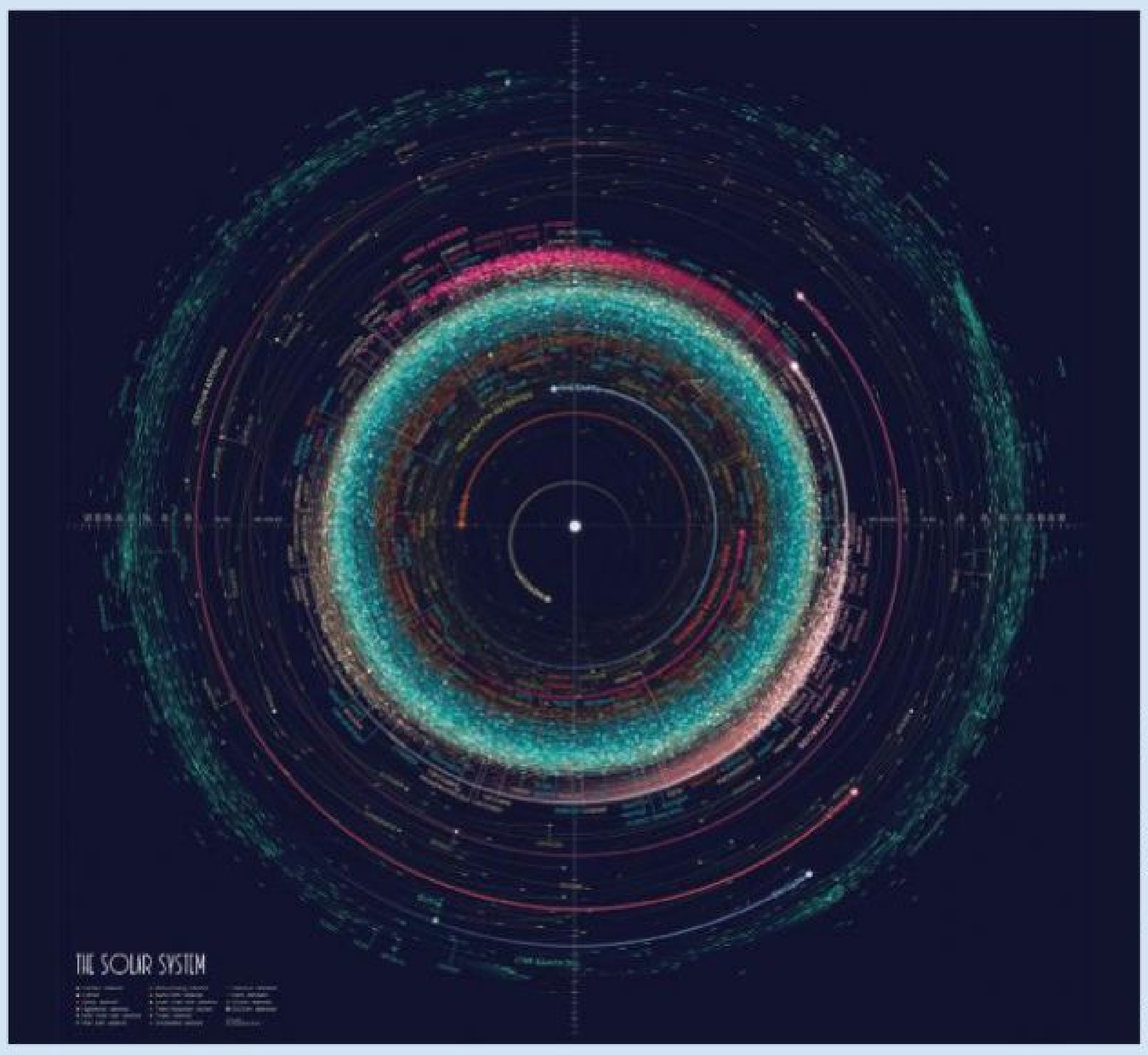
Words by **Brandon Specktor**

In most maps of the Solar System you can expect to see the eight canonical planets, and often Pluto, trailing the fiery orange Sun like polite little ducklings in a row. In biologist Eleanor Lutz's new map of the Solar System, which shows the precise orbital paths of more than 18,000 near celestial objects, you'll be lucky if you can even find Mars.

Lutz is a doctoral candidate at the University of Washington who spends her evenings turning public datasets into hyperdetailed works of art. In her new project, called the Atlas of Space, she's borrowed more than a decade of data compiled by the likes of NASA, the US Geological Survey and other science organisations to create some of the most accurate maps of the Solar System that will fit on your bedroom wall.

The map shown here, which Lutz posted to her website **tabletopwhale.com** on 10 June, was created from orbital data taken from a dozen different public databases. Going above and beyond most textbook space maps, this guide to the cosmos shows the asteroid belt between Mars and Jupiter and the Kuiper Belt beyond Neptune in gorgeous, chaotic detail.

"This map shows each asteroid at its exact position on New Years' Eve 1999," Lutz wrote on her site. "This map shows the orbits of more than 18,000 asteroids in the Solar System. This includes everything we know of that's over ten kilometres (6.2 miles) in diameter – about 10,000 asteroids – as well as 8,000 randomised objects of unknown size."



The map plots objects in their position before the turn of the millennium

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David M. Harland

Life might be even more likely on Mars than initially thought

© NASA

Martian microbes could survive in Mars' salty puddles

Words by **Charles Q. Choi**

In extraordinarily salty puddles of water resembling ones you might find on Mars, bacteria can survive getting completely dried out, suggesting that the Red Planet may be more habitable than previously thought, according to a new study.

Just before dawn, evaporating frost on the Martian surface can drive humidity up to 100 per cent, said the study's senior author Mark Schneegurt, an astrobiologist at Wichita State University in Kansas. At its peak the humidity on Mars can resemble the drier parts of the Atacama Desert in Chile, the driest place on Earth aside from its poles, which nevertheless is home to life.

In addition, a variety of salts often found on the surface of Mars could absorb this moisture. Because the briny fluids that result have a lower freezing point than water, they could withstand the frigid temperatures that prevail on the Red Planet's surface – and potentially harbour life.

However, the humidity on the Martian surface plummets during the daytime as temperatures rise. As such, any microbes on Mars would likely have to deal with constantly getting dried out.

To see if life on Mars could survive these cycles of desiccation, scientists experimented with two species of bacteria taken from two highly salty areas – Hot Lake in Washington and the Great Salt Plains in Oklahoma. They grew them in the lab in a solution that was half water and half magnesium sulphate, commonly known as Epsom salt, a kind of salt common on the Martian surface.

Researchers next dried small drops of this bacterial-laden solution using water-absorbing chemicals under a vacuum, to mimic how brines on the Martian surface might evaporate. Finally they locked the dried drops in a jar with either regular water or saltwater and let the jar fill with humidity.

Within a day the scientists found the dried drops absorbed enough moisture from the air to make a liquid brine, at which point the bacteria revived and began to grow. Typically more than half the cells survived.

Two potentially Earth-like alien planets found around nearby star

Words by **Elizabeth Howell**

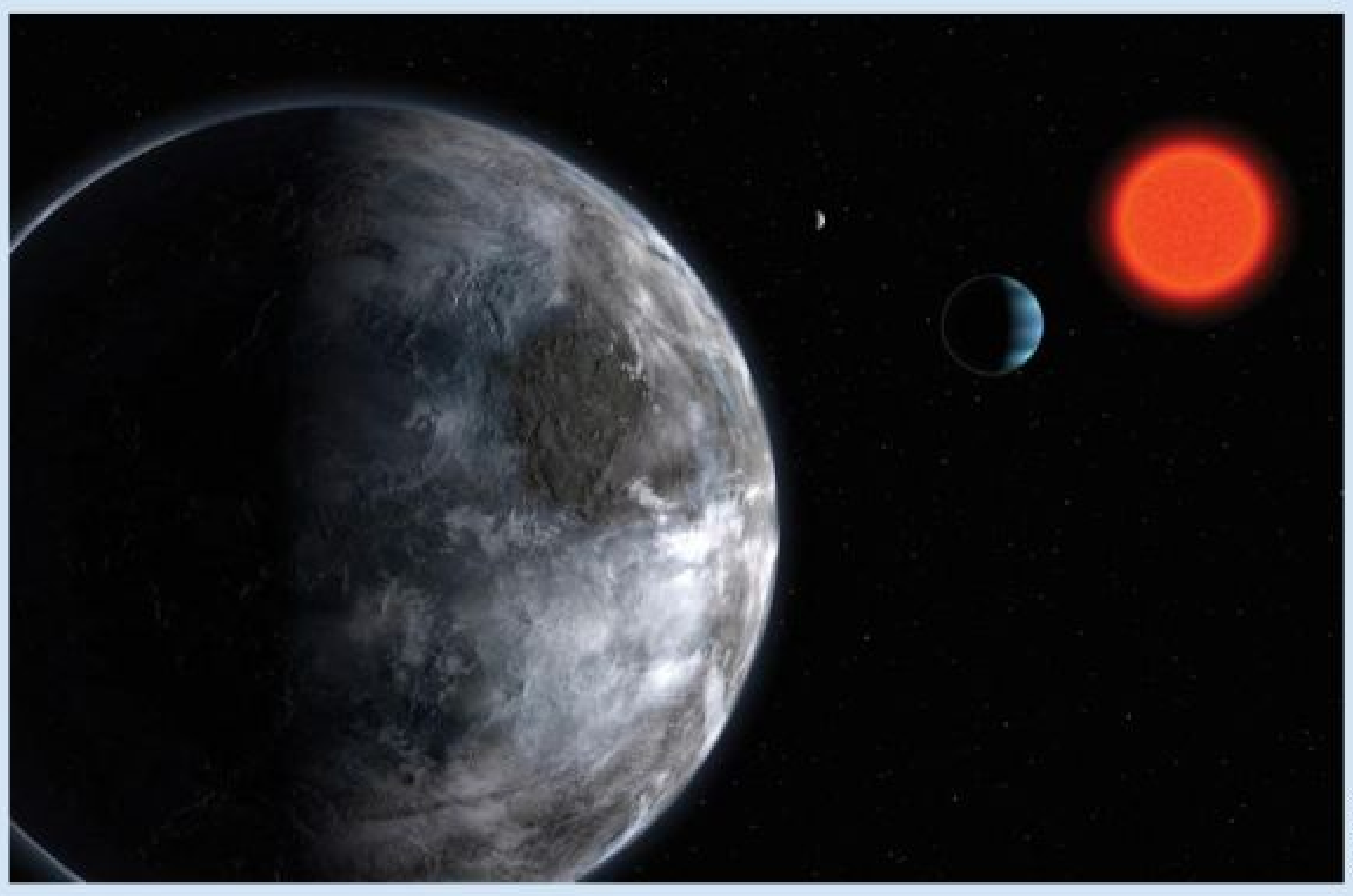
There are even more potentially habitable planets near Earth than we ever imagined. A research team discovered two Earth-like planets in our cosmic backyard, and they're located in the perfect zone for water to form on their presumably rocky surfaces.

The planets orbit a sun known as 'Teegarden's star', which is only 12.5 light years from Earth – a light year is the distance that light travels in a year, or roughly 6 trillion miles or 10 trillion kilometres. The two planets look an awful lot like Earth and our neighbouring worlds, the researchers said.

"The two planets resemble the inner planets of our Solar System," lead author Mathias Zechmeister, a research scientist at the Institute for Astrophysics at the University of Göttingen in Germany, said in a statement. "They are only slightly heavier than Earth and are located in the so-called habitable zone, where water can be present in liquid form."

According to observations, the newly found worlds orbit their parent star with periods of roughly five days and 11 days respectively. That's very quick compared to planets orbiting our own Sun – even Mercury takes 88 days for a single circuit – but Teegarden's star is an M dwarf – a type of star that produces less light and energy than our own Sun. Any potentially habitable worlds would be found huddled closer to this star than Earth is to the Sun, or their water would freeze. Thus, their orbits would be quicker.

More planets could be lurking in Teegarden's star's solar system, the research team added, as many stars have more than a couple of planets orbiting them.



© ESO

The comet won't yet have interacted with the solar wind

© ESA

'Comet Interceptor' to explore an undiscovered space object

Words by **Passant Rabie**

A new mission will intercept an undiscovered comet en route to Earth's orbit, the first of its kind to observe a pristine interstellar object as it enters the inner Solar System.

Three spacecraft will take snapshots of the comet from different angles, creating a three-dimensional profile of the object and characterising its surface, composition, shape and structure.

The 'Comet Interceptor' was selected by the European Space Agency (ESA) on 19 June as the latest 'fast' or F-class mission – in reference to its quick implementation. The mission's proposal was submitted to the ESA in March, and it is scheduled to launch in 2028.

"Pristine or dynamically new comets are entirely uncharted," Günther Hasinger, ESA's director of science, said in a statement. "[They] make compelling targets for close-range spacecraft exploration to better understand the diversity and evolution of comets."

The mission is unique in that it will observe a comet that has not yet interacted with the solar wind environment – and it will launch before its target has been discovered. By observing the comet as it enters the Solar System it can provide information on the evolution of comets as the object will likely contain material that has not yet been altered since the birth of the Solar System.

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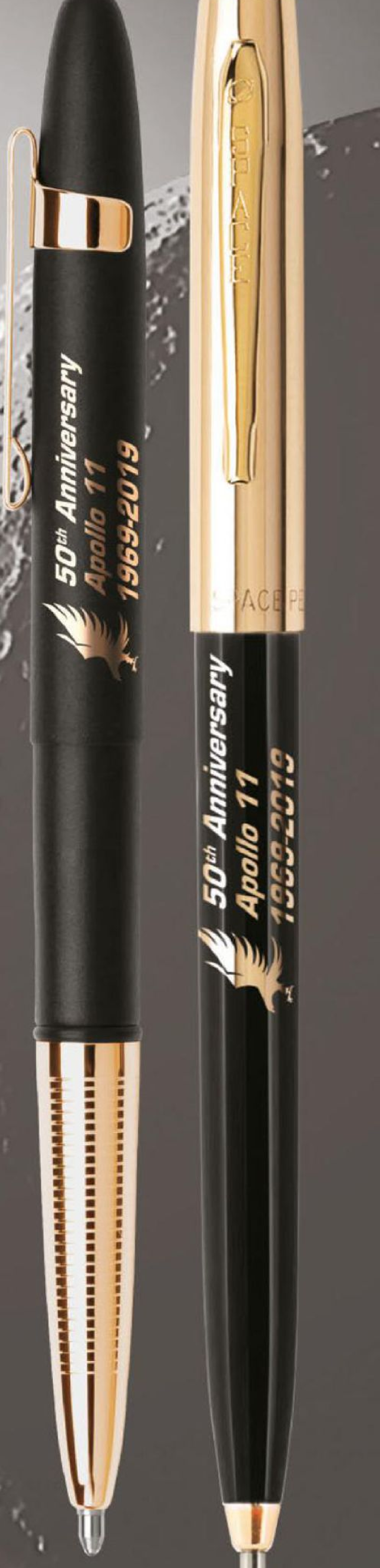

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THE SECRETS OF APOLLO 1

Buzz Aldrin & the last crew

unpublished archives of the

members reveal the 1969 Moon landing

Exactly 50 years ago, humankind achieved one of the greatest technical feats of all time. Less than nine years after President Kennedy had set the goal of landing a man on the surface of the Moon and returning him safely to Earth, NASA achieved that most astonishing aim on 20 July 1969.

Those intervening years had been a white-knuckle ride. Beginning with Alan Shepard's 15-minute suborbital Mercury flight in 1961, NASA progressed through a series of milestones in their mission to reach the Moon. There was the loss of a Mercury capsule and the near-drowning of its pilot Gus Grissom; John Glenn's re-entry with a retrorocket still attached to his Friendship 7 capsule; a slew of hugely successful Gemini missions, including one that almost span out of control, potentially threatening the life of the astronaut who in 1969 would take that first historic step and then four fully flown Apollo missions: two in low-Earth orbit, two that orbited the Moon and only one to test the full system. NASA had to endure the catastrophic loss of Grissom and his two crew mates, Edward White and Roger Chaffee, in 1967 in Apollo 1's tragic fire on the launch pad, but the space agency had resolved to carry on, completely redesigning the Lunar Command Module and carrying out major changes to the Lunar Landing Module – the LEM as it was known – in that short space of time.

> "A space mission will never be routine. You're putting three humans on top of an enormous amount of high explosive" Gene Kranz

Amid triumph and tragedy, on 16 July 1969 NASA was ready to go to the Moon. Yet the trials and tribulations of the previous years were not over, and the three-man crew of Apollo 11 – Neil Armstrong, Buzz Aldrin and Michael Collins – were facing one of the most dramatic spaceflights in history. We recall the historic first words said on the lunar surface and the elation of the largest TV audience in history at that time when they saw those grainy black-and-white images from the Moon, but there is so much more to the story of Apollo 11 that may not be as well known.

Their first task, of course, was to leave Earth on top of the mighty Saturn V rocket – the tallest, most powerful rocket ever built. Many astronauts who were propelled into space by the Saturn V describe it as being a very smooth ride. Neil Armstrong is quoted as saying that while the launch for all those watching on Cocoa Beach or at Cape Canaveral was deafening, the crew could only detect a slight increase in background noise,

© NASA/Getty

No escape plan: what NASA didn't want the astronauts to know

A secret launch document revealed that an escape plan – should the Saturn V rocket fail – was bogus

What the astronauts were told

The crew were told that should the leak cause an engine to fail at liftoff, their capsule would eject to safety far away from the failing, exploding rocket. To their knowledge, Armstrong and his crew had been sufficiently trained to escape.

What would have happened

Apollo 11 would not be saved if something had gone wrong in the first two minutes after liftoff. The abort system needed two seconds after detection of a catastrophic failure to activate the launch escape system. If an engine were to go out on the first stage, within half a second the Saturn V would have broken up and killed the crew.

a lot of shaking and feeling akin to being on board a large jet aeroplane on takeoff. Yet as smooth a ride as it was, being on top of that much rocket fuel was always a dangerous experience. "A space mission will never be routine because you're putting three humans on top of an enormous amount of high explosive," Gene Kranz, flight director for Apollo 11's lunar landing, told us. If there were any nerves, the astronauts weren't feeling it, according to Buzz Aldrin. "We felt that our survival was in the probability of 99 per cent. There were a lot of risks involved but there were a lot of points to abort the mission short of continuing on something risky."

Once in space the Command Service Module had to rotate and dock with the Lunar Module, which was embedded in the final S-IVB stage of the Saturn V rocket. After the two spacecraft had mated, onwards they flew to the Moon, leaving the S-IVB stage trailing in space behind them. Some time later, the crew spotted something strange outside: a light that appeared to be following them. When Michael Collins used the onboard telescope to view it, he couldn't make it out – it looked like a series of ellipses, and when focusing the telescope it seemed L-shaped, but that could have just been the way sunlight was glinting off it.

Reticent to tell mission control in Houston, Texas, that they were being raced to the Moon by a UFO, the crew cautiously asked where the SIVB rocket stage was. "A few moments later they came back to us and said it was around 6,000 miles [9,656 kilometres] away," recalled Aldrin. "We really didn't think we were looking at something that far away, so we decided to go to sleep and not talk about it anymore." Aldrin doesn't believe it was an alien spaceship, but that it was more likely the Sun reflecting off one of four metal panels that fell away from the rocket stage when they docked with the Lunar Module. For almost four days Apollo 11 flew towards the Moon, where Armstrong and Aldrin climbed into the Lunar Module – the 'Eagle' – and said goodbye to Collins, who was to remain in the Command Module in orbit around the Moon.

As the Eagle flew around the far side of the Moon, things in mission control were growing tense. "There was a degree of seriousness in mission control that I hadn't even seen in training," said Kranz. "That was when you realised this was the real deal: today, we land on the Moon." Almost immediately after separating from the Command Module there were problems. Radio communication with the Eagle was sketchy at best, and they were coming up to the point where the landing could no longer be aborted if something was wrong.

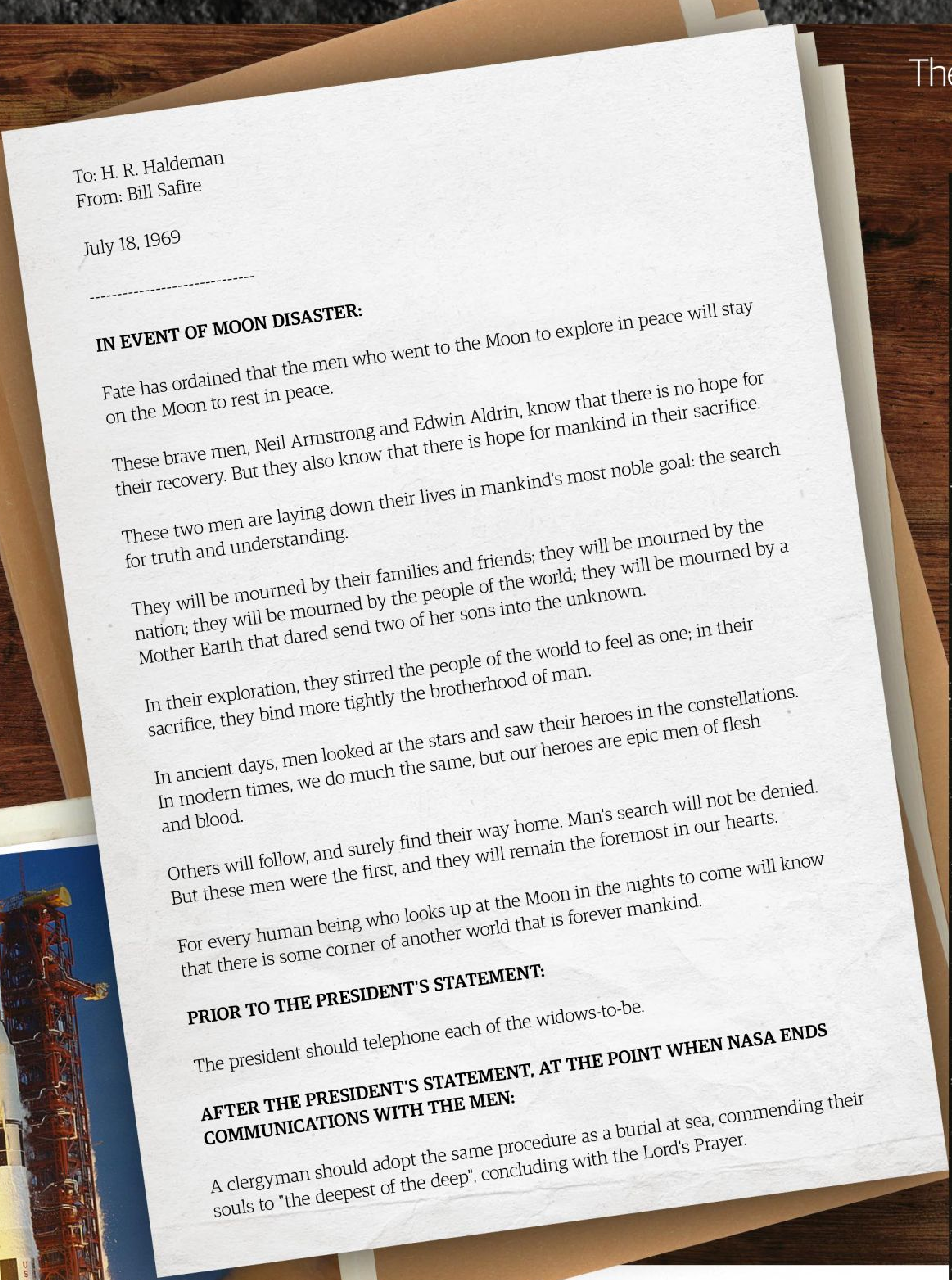
"It was up to me to decide if we had enough information to make the go/no-go [decision] and continue the descent to the Moon," said Kranz. So, five minutes before the powered descent to the lunar surface was due to begin, with radio communication cutting in and out, Kranz asked

> "There was a degree of seriousness in mission control that I hadn't even seen in training"
>
> Gene Kranz

Left: The Apollo 11 crew 'suit up' for a countdown demonstration test

Right top: The huge Saturn V rocket carries three men towards the Moon

Right bottom: In his spacesuit, Neil Armstrong practises getting back to the first rung of the ladder on the Lunar Module



To: H. R. Haldeman
From: Bill Safire

July 18, 1969

IN EVENT OF MOON DISASTER:

Fate has ordained that the men who went to the Moon to explore in peace will stay on the Moon to rest in peace.

These brave men, Neil Armstrong and Edwin Aldrin, know that there is no hope for their recovery. But they also know that there is hope for mankind in their sacrifice.

These two men are laying down their lives in mankind's most noble goal: the search for truth and understanding.

They will be mourned by their families and friends; they will be mourned by the nation; they will be mourned by the people of the world; they will be mourned by a Mother Earth that dared send two of her sons into the unknown.

In their exploration, they stirred the people of the world to feel as one; in their sacrifice, they bind more tightly the brotherhood of man.

In ancient days, men looked at the stars and saw their heroes in the constellations. In modern times, we do much the same, but our heroes are epic men of flesh and blood.

Others will follow, and surely find their way home. Man's search will not be denied. But these men were the first, and they will remain the foremost in our hearts.

For every human being who looks up at the Moon in the nights to come will know that there is some corner of another world that is forever mankind.

PRIOR TO THE PRESIDENT'S STATEMENT:

The president should telephone each of the widows-to-be.

AFTER THE PRESIDENT'S STATEMENT, AT THE POINT WHEN NASA ENDS COMMUNICATIONS WITH THE MEN:

A clergyman should adopt the same procedure as a burial at sea, commending their souls to "the deepest of the deep", concluding with the Lord's Prayer.

his flight controllers to give him their go/no-go based on the last frame of data that they saw. They all said "go." And then things turned from bad to nearly catastrophic. The spacecraft's guidance computer, developed at MIT under the auspices of Charles Draper – the lab at MIT now bears his name – was a 2MHz system that was the first in the world to use integrated circuits. Its fixed memory was an ingeniously designed 'Core Rope' which consisted of a set of small hoops. 'Little Old Ladies', as it was referred to at the time, along with machines would thread the code either through or around the hoops to give the computer its 1 or 0 value. If the MIT code was threaded incorrectly, the 'programmer' would have to laboriously go through the woven cores and debug it. When the crew were approaching the Moon for the landing, various alarms were triggered by the computer. "Whatever information we were looking at [disappeared] and instead it gave us the code number of the alarm," said Aldrin. "It was

Mission control loses contact with Apollo 11

Alarms, loss of communication and system failures plagued the first mission to land on the Moon

03:04:15:47
"Apollo 11, Apollo 11, this is Houston. Do you read? Over."
Bruce McCandless, CAPCOM

03:04:15:59
"Apollo 11, Apollo 11, this is Houston. Do you read? Over."
Bruce McCandless, CAPCOM

03:04:17:00
"Apollo 11, Apollo 11, this is Houston. We are reading you weakly. Go ahead. Over."
Bruce McCandless, CAPCOM

03:04:19:32
"Apollo 11, this is Houston. Are you in the process of acquiring data on the burn? Over."
Bruce McCandless, CAPCOM

03:04:21:37
"Apollo 11, Apollo 11, this is Houston. How do you read?"
Bruce McCandless, CAPCOM

03:04:16:11
"…"
Unidentified crew member, Apollo 11

03:04:16:59
"Houston, Apollo 11. Over."
Unidentified crew member, Apollo 11

03:04:21:43
"Reading you loud and clear, Houston. How's us?"
Neil Armstrong, Apollo 11 commander

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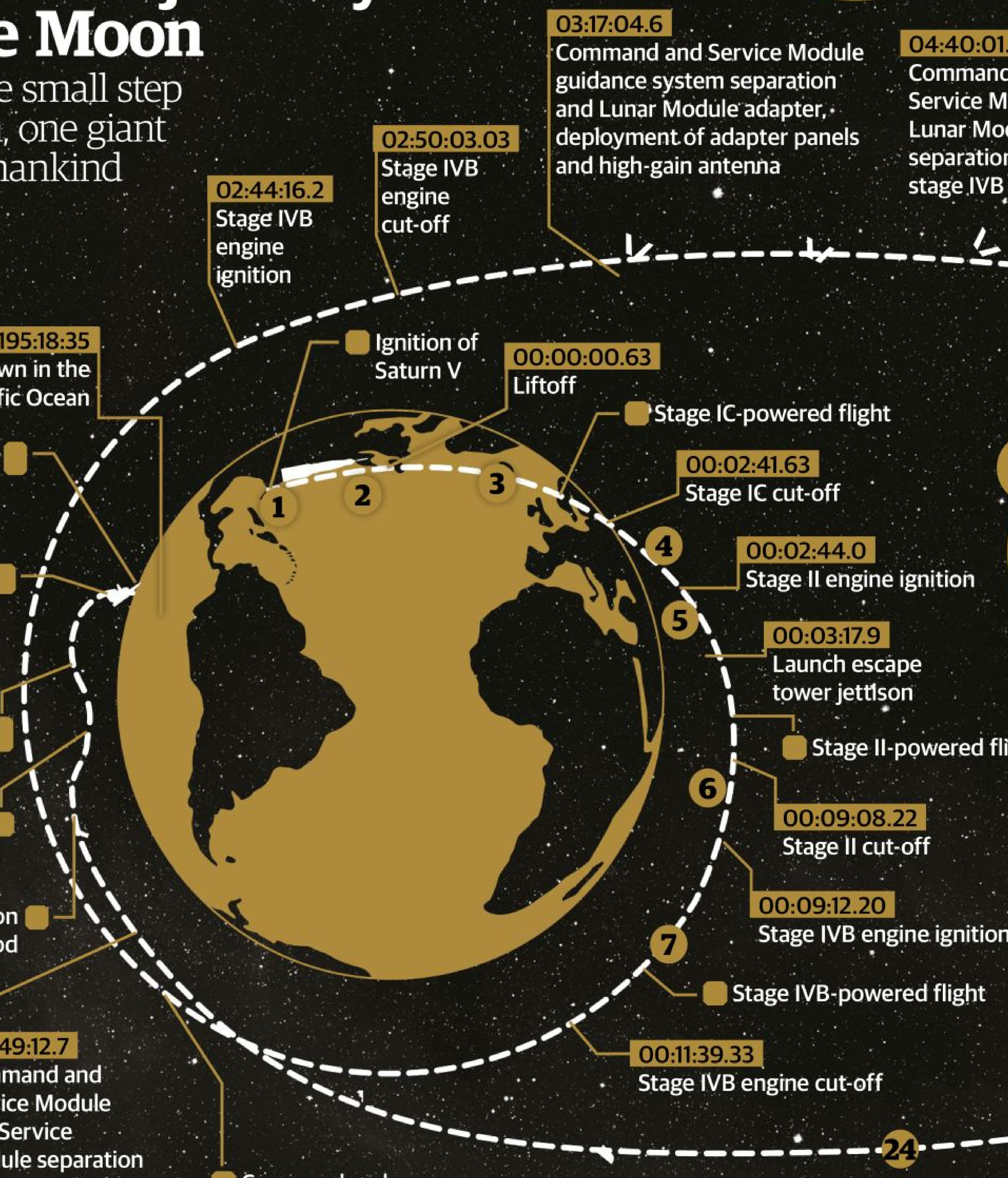
Apollo 11's journey to the Moon

It was one small step for a man, one giant leap for mankind

1

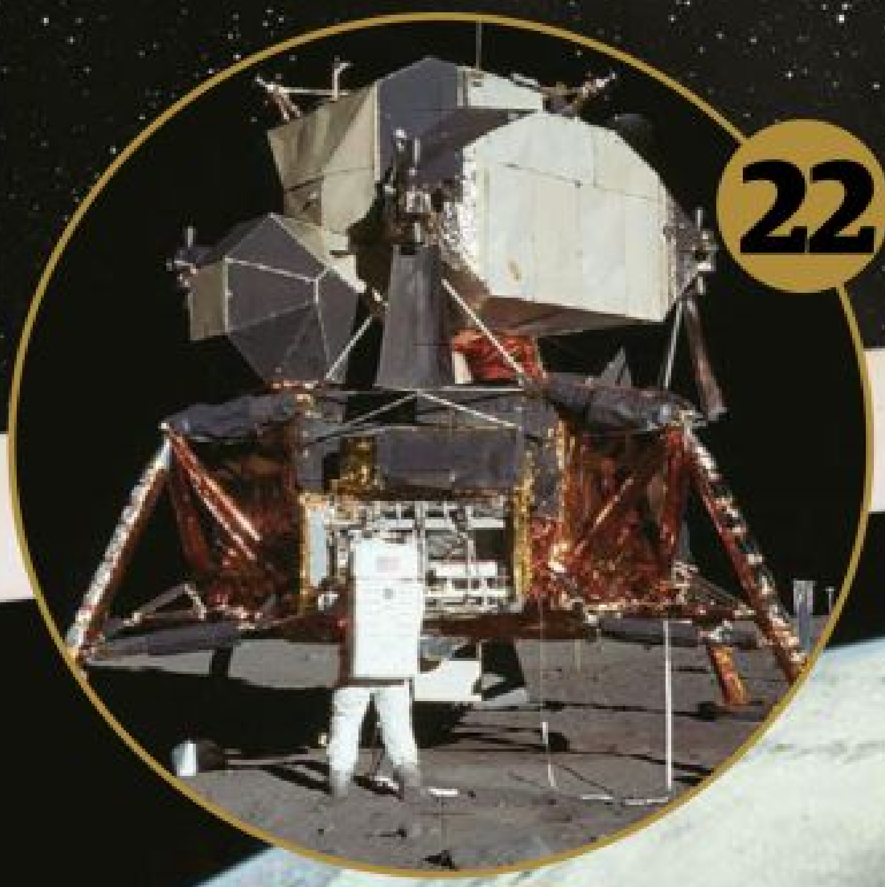
3


03:17:04.6
Command and Service Module guidance system separation and Lunar Module adapter, deployment of adapter panels and high-gain antenna
04:40:01.8
Command and Service Module/ Lunar Module separation from stage IVB
02:50:03.03
Stage IVB engine cut-off
02:44:16.2
Stage IVB engine ignition
Navigation sightings
04:44:04.65
Service Module engine cut-off
195:18:35
Touchdown in the Pacific Ocean
Ignition of Saturn V
00:00:00.63
Liftoff
04:40:01.72
Service Module ignition
Stage IC-powered flight
Deploy main chute at 3,048m (10,000 ft)
00:02:41.63
Stage IC cut-off
1
2
3
4
Heat shield and chute deployed at 7,315m (24,000ft)
00:02:44.0
Stage II engine ignition
5
00:03:17.9
Launch escape tower jettison
76,200m (250,000 ft) altitude
Stage II-powered flight
6
60,960m (200,000 ft) altitude
00:09:08.22
Stage II cut-off
00:09:12.20
Stage IVB engine ignition
Communication blackout period
7
Stage IVB-powered flight
194:49:12.7
Command and Service Module and Service Module separation
00:11:39.33
Stage IVB engine cut-off
23
150:30:07.4
Service Module engine cut-off
24
44 hours
Systems status checks
Eat and sleep periods
Data transmit periods
Command and Service Module guidance system reference alignment

6

7

21



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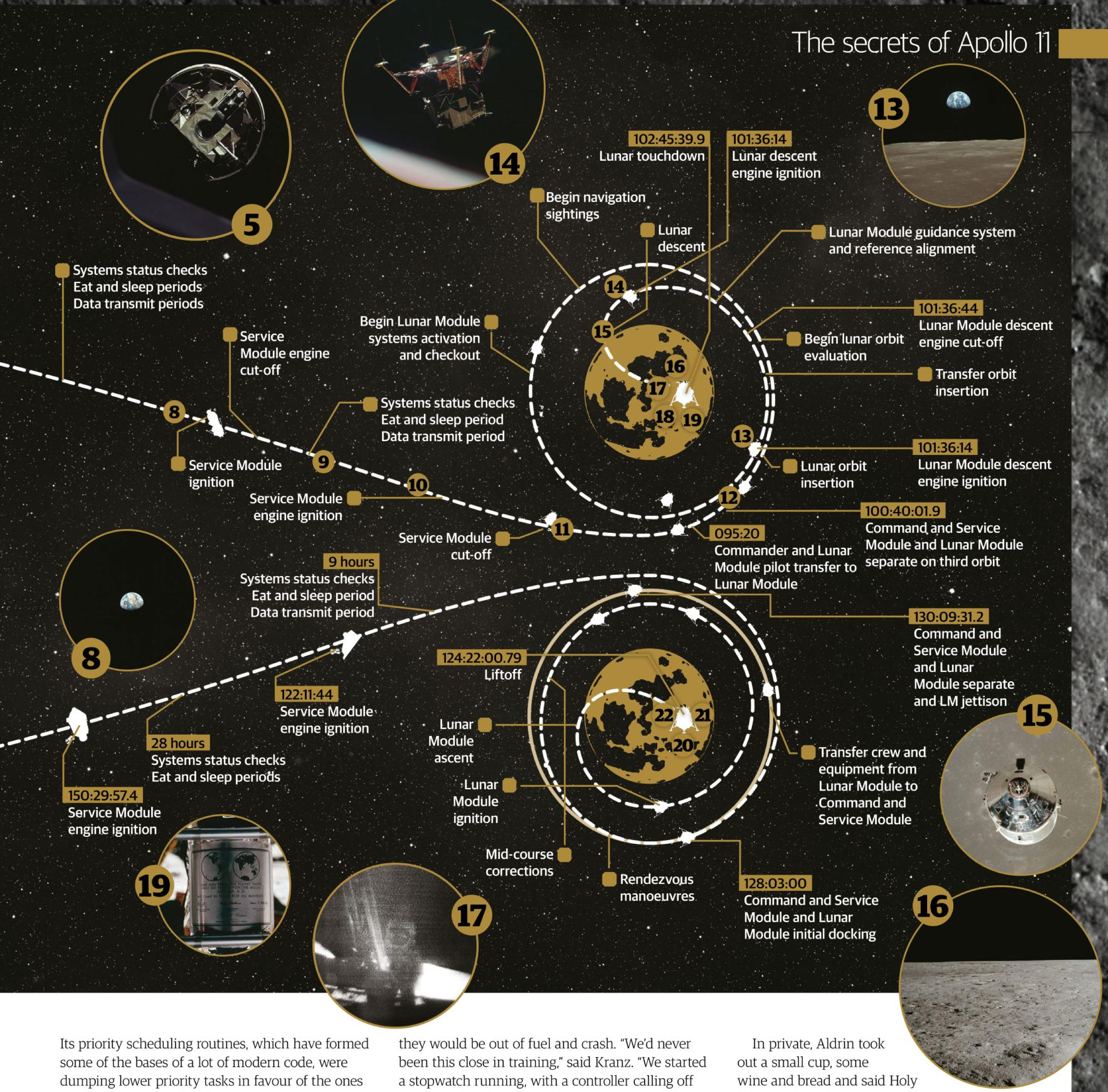
disturbing and distracting and we didn't know what it meant."

The 1201 and 1202 alarms were obscure codes - and in effect the same error - that flashed up as Armstrong manually attempted to bring the Lunar Module down. Nobody seemed to know what the codes meant, except for two men: Jack Garman, a NASA computer engineer who had come across the codes before during a practice run, and Steve Bales, who was the Apollo guidance officer. The alarms were being caused by a problem with the landing radar that was stealing precious computing cycles, and the throttle control algorithm was barely working. The computer's 72kb of memory, barely enough to write a sentence in a modern word processor, was struggling as commands into it overflowed. Garman knew that it was safe to continue and allow the computer to handle matters.


5
14
13
102:45:39.9
Lunar touchdown
101:36:14
Lunar descent engine ignition
Begin navigation sightings
Lunar descent
Lunar Module guidance system and reference alignment
Systems status checks
Eat and sleep periods
Data transmit periods
Begin Lunar Module systems activation and checkout
Service Module engine cut-off
101:36:44
Lunar Module descent engine cut-off
Begin lunar orbit evaluation
Transfer orbit insertion
Systems status checks
Eat and sleep period
Data transmit period
Service Module ignition
Lunar orbit insertion
101:36:14
Lunar Module descent engine ignition
Service Module engine ignition
100:40:01.9
Command and Service Module and Lunar Module separate on third orbit
Service Module cut-off
095:20
Commander and Lunar Module pilot transfer to Lunar Module
9 hours
Systems status checks
Eat and sleep period
Data transmit period
130:09:31.2
Command and Service Module and Lunar Module separate and LM jettison
124:22:00.79
Liftoff
122:11:44
Service Module engine ignition
Lunar Module ascent
28 hours
Systems status checks
Eat and sleep periods
Transfer crew and equipment from Lunar Module to Command and Service Module
150:29:57.4
Service Module engine ignition
Lunar Module ignition
Mid-course corrections
Rendezvous manoeuvres
128:03:00
Command and Service Module and Lunar Module initial docking
8
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Its priority scheduling routines, which have formed some of the bases of a lot of modern code, were dumping lower priority tasks in favour of the ones critical to the lunar landing.

As the Eagle approached the surface on automatic, Armstrong and Aldrin realised that the scenery outside of the window didn't look familiar to them. "I think we may be a little long," commented Armstrong, referring to the Eagle having overshot its planned landing site. Looming ahead of them was a dangerous-looking boulder field, and coming down on any of those giant rocks the size of houses would have damaged or perhaps even destroyed the Eagle. Armstrong took manual control, using the thrusters to take the Eagle over the boulder field. But now fuel was running low and there was no turning back. Armstrong had to land the Eagle - somewhere, within minutes - or they would be out of fuel and crash. "We'd never been this close in training," said Kranz. "We started a stopwatch running, with a controller calling off seconds of fuel remaining."

If things were tense in mission control, on board the Eagle Armstrong and Aldrin had everything under control. With only 13 seconds of fuel left Apollo 11 made its safe landing in the Sea of Tranquillity. History had been made. "Houston, Tranquillity Base here," Armstrong radioed home. "The Eagle has landed."

In private, Aldrin took out a small cup, some wine and bread and said Holy Communion. The wine, under one-sixth Earth gravity, apparently curled up in the cup. After reading a section of the Gospel of St John, Aldrin said a few words, with Armstrong respectfully looking on. NASA had been threatened with legal action by Madalyn Murray O'Hair, an atheist, after the crew of Apollo 8 had read from the book of Genesis, so Aldrin's heartfelt ceremony

"We felt that our survival was in the probability of 99 per cent. There were a lot of risks involved" Buzz Aldrin

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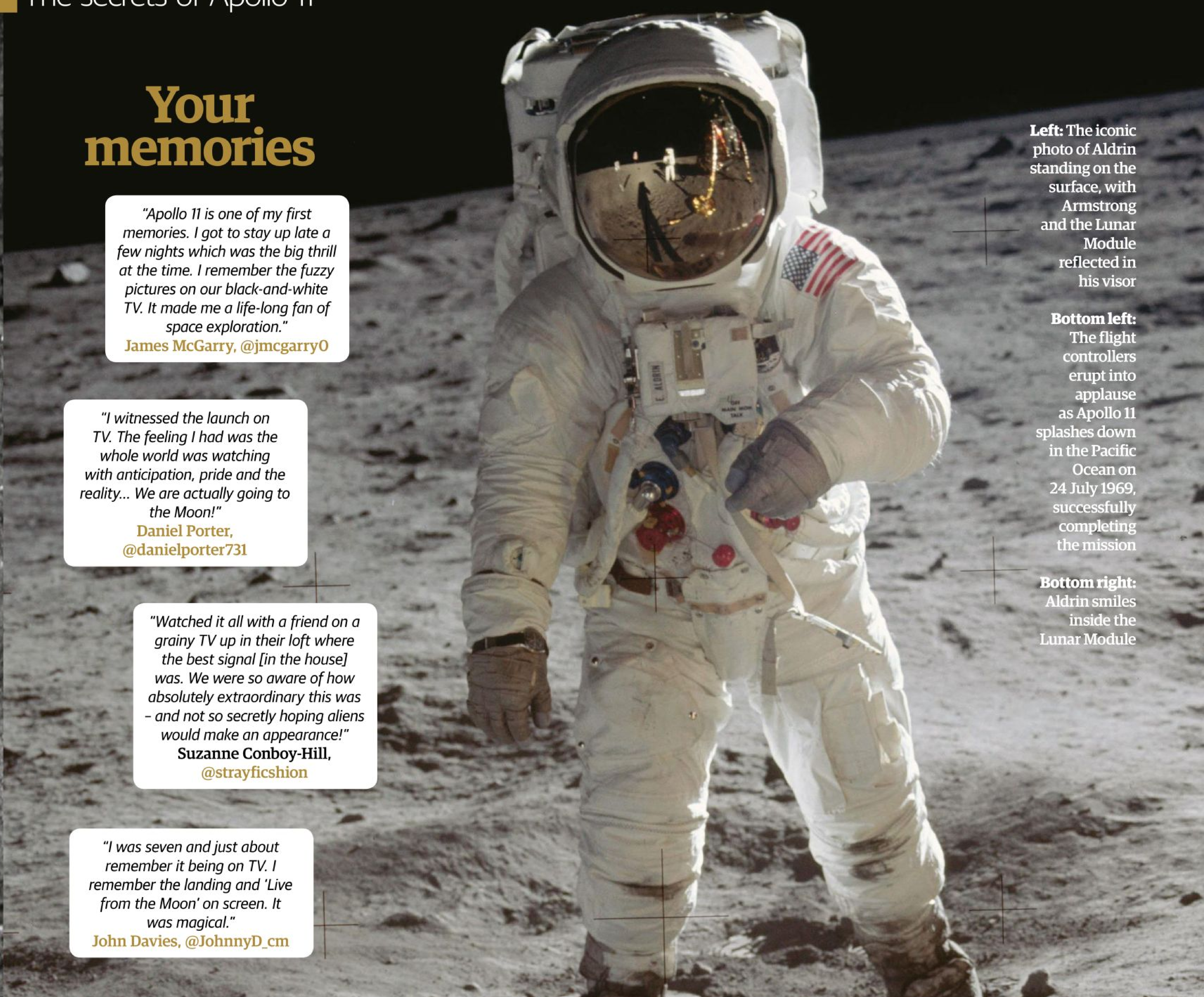
Your memories



"Apollo 11 is one of my first memories. I got to stay up late a few nights which was the big thrill at the time. I remember the fuzzy pictures on our black-and-white TV. It made me a life-long fan of space exploration."
James McGarry, @jmcgarry0

"I witnessed the launch on TV. The feeling I had was the whole world was watching with anticipation, pride and the reality… We are actually going to the Moon!"
Daniel Porter, @danielporter731

"Watched it all with a friend on a grainy TV up in their loft where the best signal [in the house] was. We were so aware of how absolutely extraordinary this was – and not so secretly hoping aliens would make an appearance!"
Suzanne Conboy-Hill, @strayficshion

"I was seven and just about remember it being on TV. I remember the landing and 'Live from the Moon' on screen. It was magical."
John Davies, @JohnnyD_cm

Left: The iconic photo of Aldrin standing on the surface, with Armstrong and the Lunar Module reflected in his visor

Bottom left: The flight controllers erupt into applause as Apollo 11 splashes down in the Pacific Ocean on 24 July 1969, successfully completing the mission

Bottom right: Aldrin smiles inside the Lunar Module never made it to the airwaves. Aldrin, though, has always been content in the thought that the first food and drink consumed on the lunar surface were communion items.

The original plan had been for the crew to get some sleep, but with that much adrenaline pumping through their veins that was never going to happen. At 02:39 UTC on the morning of 21 July, Armstrong made his way through the hatch and down the ladder before stepping foot on the surface of the Moon for the first time and saying those immortal words: "That's one small step for [a] man, one giant leap for mankind."

After exiting the Lunar Module, Armstrong and Aldrin only had a few hours to not only collect precious rock samples, but also deploy a series of experiments on the lunar surface. Solar wind experiments, a laser retro-reflector that is still used to this day to measure the Earth-Moon distance, seismometers and more were all deployed. Armstrong is cited as saying he felt like a five year old in a candy store, with not enough time to do all the things he wanted to. Standing on the Moon must have been an incredible experience. Aldrin described the scene around him as one of "magnificent desolation", adding that "you could look at the horizon and see very clearly because there was no atmosphere, ther was no haze or anything".

As Armstrong walked around setting up instruments and picking up rocks, Aldrin hopped around on the surface, testing what the best way to move about in the low gravity was. Most of the pictures taken during the landing are of Aldrin on the surface; barely half a dozen show Armstrong, and none clearly. That's because Armstrong had the camera for most of the Moon walk. While on the surface, the crew also had terrific problems with the American flag. It had a telescoping boom arm to hold it out in lieu of any wind to hold it up. The two astronauts wrestled to get the boom arm to extend fully, but it would not, so the flag had a small kink in it. They also found that it was almost impossible to get the flagpole to go deep enough into the ground and, in the end, they only just managed to get it to stay upright. Both of the crew worried it would fall over live on TV, and probably as President Nixon was on the phone to them. But it remained upright during the broadcasts and telephone calls.

After collecting their rocks and clambering back into the Lunar Module, the crew took off their boots and backpacks, and began to throw anything not of vital importance back onto the lunar surface. This included urine bags, empty food packs, empty cameras and so on. But to the crew, they were just getting in the way and not needed. There was time for one final crisis. The interior of the Lunar Module was cramped and, moving around in their bulky spacesuits, one of the astronauts had knocked out the switch for the circuit breaker that fired the ascent rocket that would take them home.

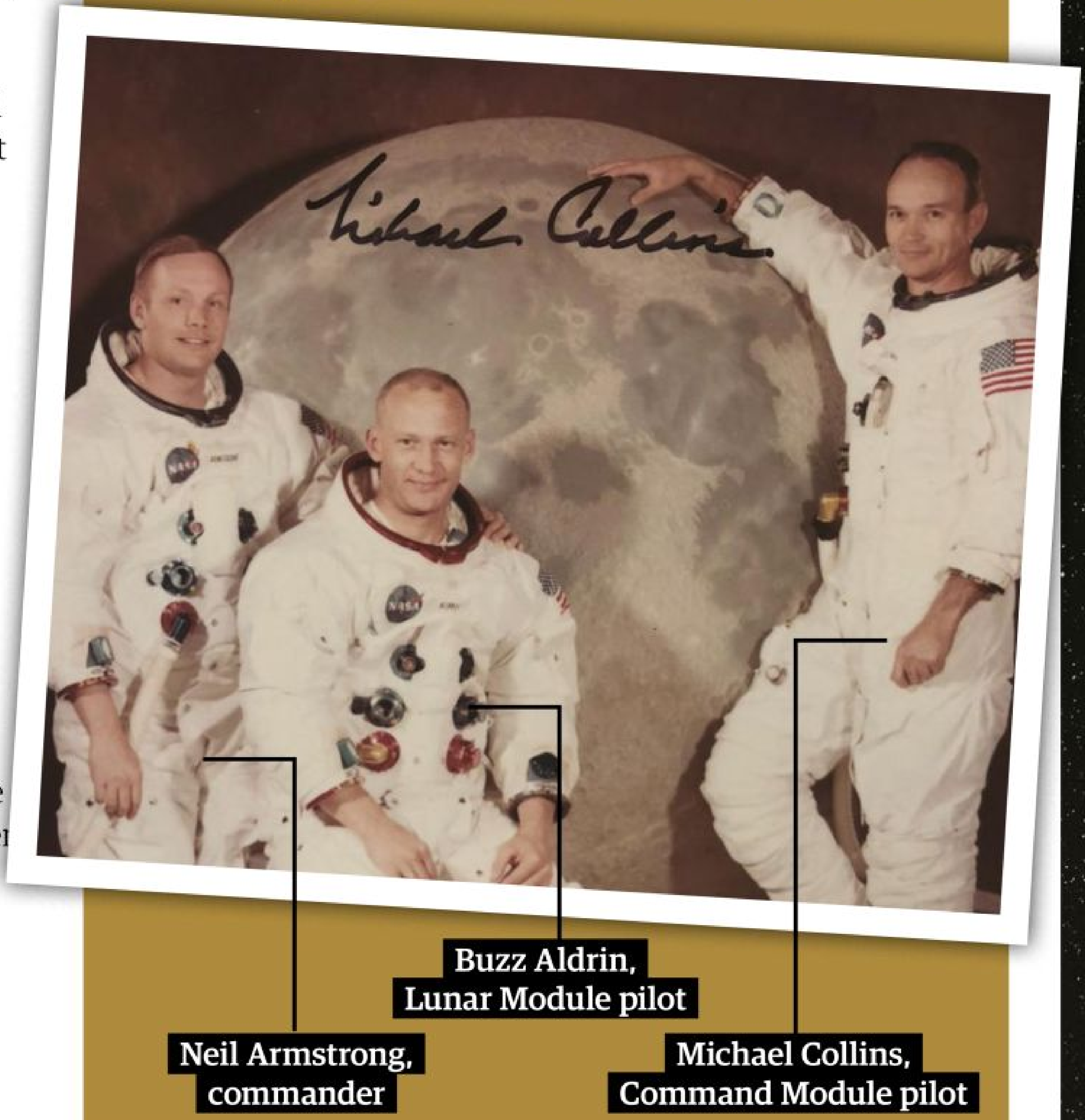
This was a real bottleneck moment for the mission. "If for some reason the ascent engine didn't work, there was no way to rescue the crew," said Kranz. Armstrong and Aldrin would be stranded on the Moon. The concern was so serious that President Nixon had a speech prepared, while mission control would close down communications with Armstrong and Aldrin after a clergyman had "condemned their souls to the deepest of the deep". Without that circuit breaker the crew were facing that lonely fate, but their training would not have allowed them to give up. "Rather than worry about things like that, we'd face them when the time came and we'd work as hard as we could to fix the problem until our oxygen ran out," said Aldrin.

In the end, the solution was remarkably simple. Jabbing the end of a pen into the slot where the broken switch had been, Aldrin was able to push the circuit breaker in. The ascent rocket fired and the two Moonwalkers were on their way home, via a rendezvous with Michael Collins in the Command Module.

As the Eagle took off, the flag finally did blow over, and to this day it lays flattened, bleached out by solar radiation.

Michael Collins' forgotten photograph

The Apollo 11 Command Module pilot reveals an old photo he believes NASA never used


Michael Collins
Buzz Aldrin, Lunar Module pilot
Neil Armstrong, commander
Michael Collins, Command Module pilot

"Rather than worry, we'd face them when the time came and we'd work as hard as we could to fix the problem" Buzz Aldrin

"Neil could be very closed off emotionally"

James Hansen is the only author to write an official biography on space hero Neil Armstrong

"In some ways Neil was a very simple and very straightforward type of person, but at the same time very complex. That sounds like a contradiction, but the human personality is an amazing and difficult thing.

Neil could be very closed off emotionally in many respects, and very private and unwilling to share his inner thoughts. But at the same time – in certain social settings when he was comfortable, certainly around his fellow pilots and astronauts – he could be very friendly, had a great sense of humour and was just a great person to be around. I was interested in getting under his skin in a way. In writing the book, I didn't really want to turn it into a psychobiography where I try to apply psychology concepts to his personality. At the same time, I did want to understand what made him tick.

I'm a strong believer that the child is the father to the man. You have to really understand what goes on in childhood development, for example his parents, siblings, family and community, to really understand why a person becomes what they become."

© All photos NASA;

INTERVIEW BIO

Dr Carlo Rovelli

Rovelli is an Italian theoretical physicist born in Verona, Italy, currently working at the Centre de Physique Théorique de Luminy (Center of Theoretical Physics of Luminy) at Aix-Marseille University, France.

Carlo's last book, *Seven Brief Lessons on Physics*, tackled the evolution of physics with the introduction of Einstein's discoveries in quantum mechanics and the theory of relativity. It was so popular it sold over a million copies worldwide, and now he is back with another exciting book that brings the complicated concepts of time to the general population in an enjoyable fashion.

THE COMPLICATIONS OF TIME AND SPACE

Time is not as straightforward as we think it is. Italian theoretical physicist Carlo Rovelli speaks to **All About Space** about the enigma that is time, and how it changes throughout the cosmos

Interviewed by Lee Cavendish

What was your motivation behind *The Order of Time*? Was it something you felt needed more attention after writing *Seven Brief Lessons on Physics*?

Seven Brief Lessons has been a huge success, with over a million copies sold. It was hard to decide to write again after that. One option was to do sort of the same thing, another physics book. But then I decided that it wasn't what my readers wanted. They wanted something more sincere. So I went to what was - for me - the most fascinating problem in theoretical physics, which is the nature of time. I decided to focus on a single problem, and that problem has been the passion of my life to study: what is time? How do we think about time?

I decided to write a book which is partially a popularisation and partially also telling everything I understand about this fantastic problem, which is the nature of time and what I don't understand, including my own ideas and my own speculations and what I think are the open mysteries. It came out as a book which is quite peculiar, because it is not just popularisation but it is also - from the point of view of a scientist immersed in that - about a problem which is not fully unravelled yet.

What do you think is a common misconception about the nature of time?

Basically everything [laughs]. We have an intuition about time which works pretty well in our everyday life, but it's basically wrong if we were to make it universal. We think of time as a one-dimensional thing, just a sequence of instances - and that's wrong. We think that the past is different from the future - that is wrong. We think that at each instance, our entire universe exists in that instance, so there's there idea of 'present' over the entire universe - and that's wrong. We think that between two instances there is a fixed amount of time that any clock could measure - that's wrong.

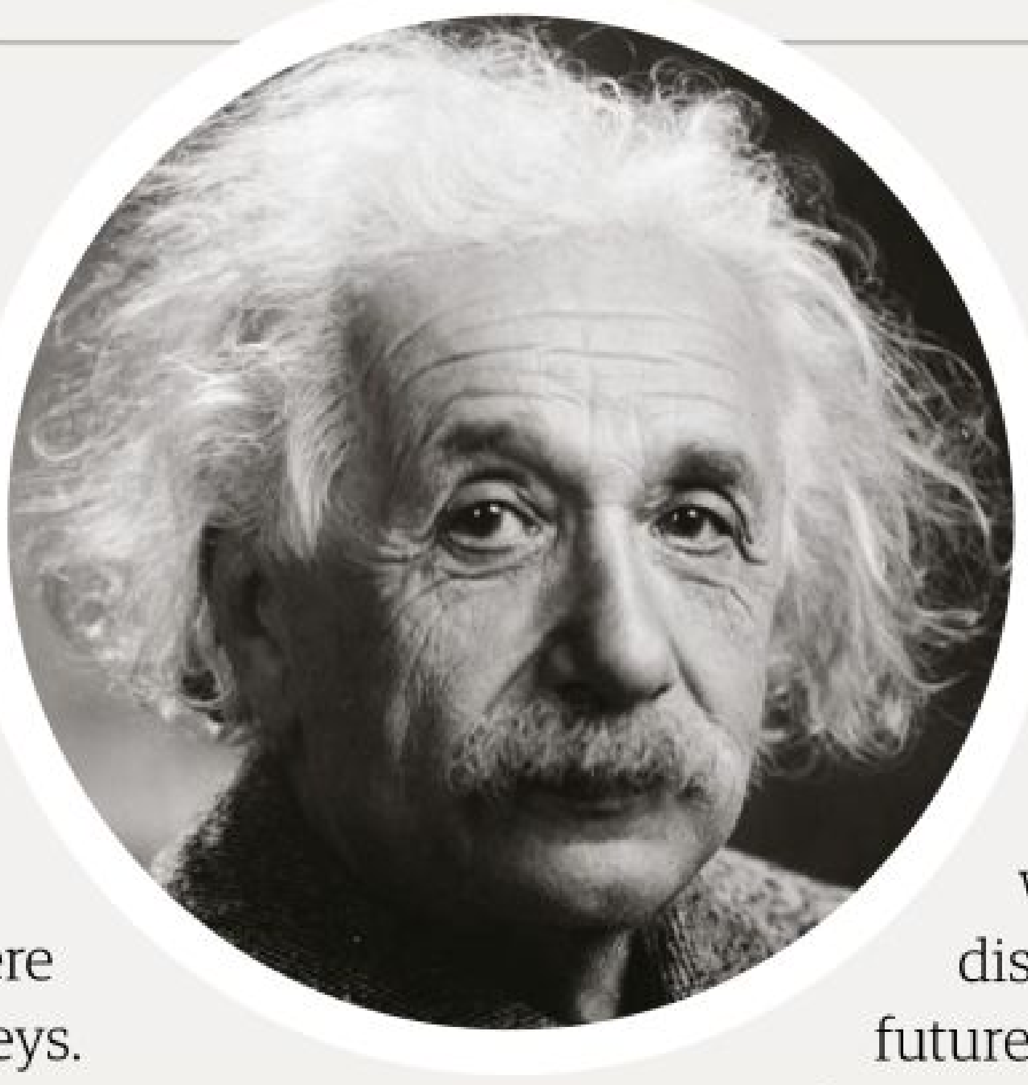
Basically, that's it. Our entire normal intuition about time is only an approximation. It's like thinking the Earth is flat, which is good as long as we're in a small patch of the Earth, but it's wrong as you look a little bit larger, and this is a fact.

How can you tell this is true though?

One example is, for instance, clocks don't go at the same speed. Clocks go at different speeds depending on altitude. For example, in the mountains there is more time compared to the valleys. For people on the International Space Station, time passes faster than down on the Earth. Near a big planet time passes slower, and even near a black hole time passes much, much slower. So the idea of a single time that passes at the same speed is completely wrong. This is just the first realisation of what we have wrong about time.

If it is not a fundamental aspect of life, then what laws govern its nature?

The main message of the book is that when we think about a common notion of time, it's really a combination of a lot of things. What we call 'time' is really a structure with a set of layers that have different origins. The properties that we usually attribute to time come from different parts of physics. For instance, the speed at which the clock moves depends on gravity - we understand this with gravitational theory. The distinction between the past and future is a completely different story, and we understand it with thermodynamics, statistical mechanics and the notion of entropy. Entropy is the many microscopic degrees of freedom of which we don't look at.



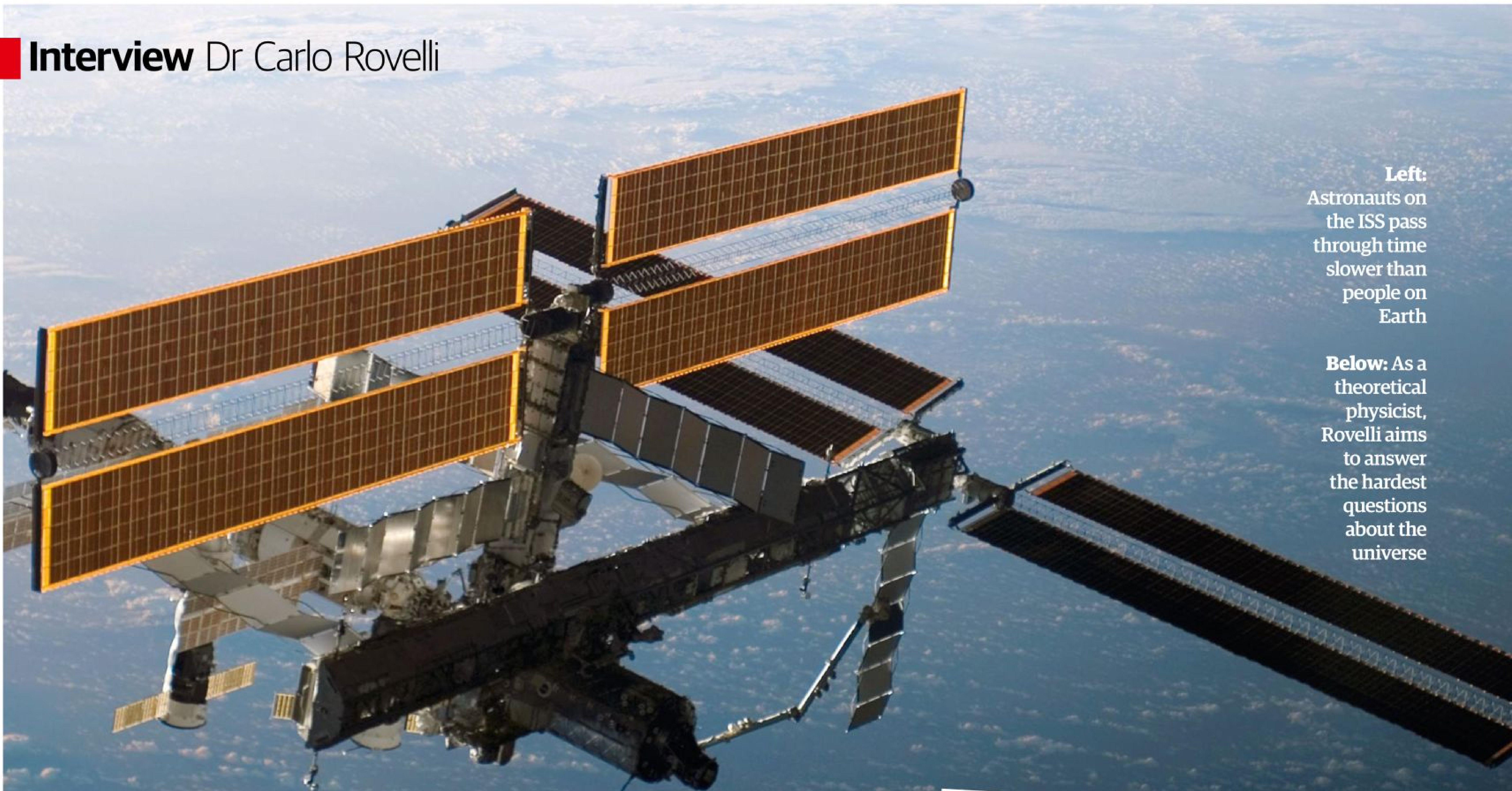
So time is like an onion: you have to take away layer by layer and understand each one with its own language. That's why it's complicated. One starts with a simple idea: I know what time is. Time passes with each day and night. It's all very simple, but then the more one studies it, the more layers there are appearing which have to be separated.

One [layer] is thermodynamics; one is general relativity. If one goes even more general to quantum gravity - which is my domain of research

Above: Einstein's work in understanding the universe had marvellous revelations about time itself

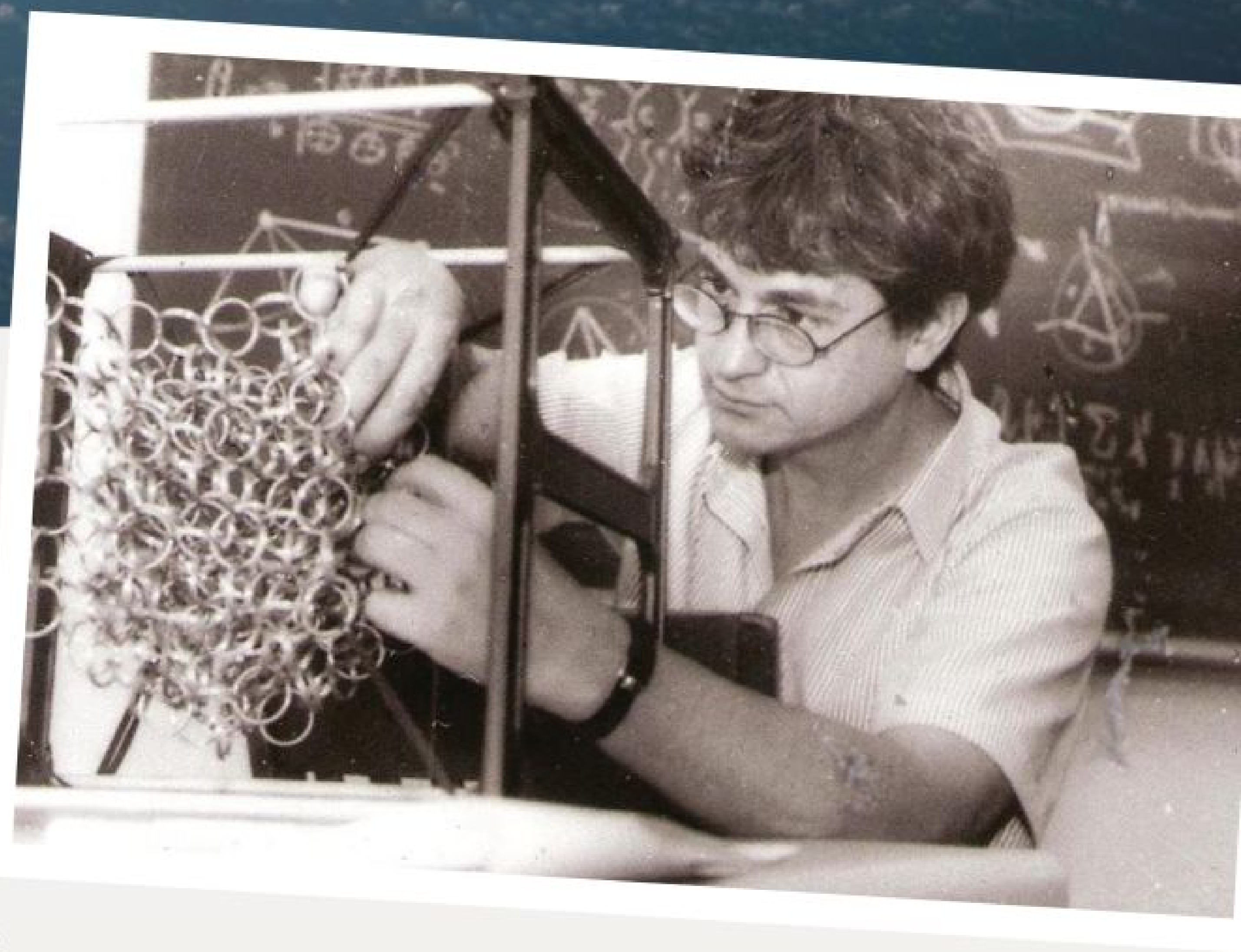
Right: Rovelli says the only things stopping us going to a black hole are technology and money

© Nicholas Forder



Left: Astronauts on the ISS pass through time slower than people on Earth

Below: As a theoretical physicist, Rovelli aims to answer the hardest questions about the universe



– then there isn't even a specific variable that works on time in the equations of quantum gravity we are working on. There's no time variable at all.

Is there any science in how we perceive time?
Perhaps the most interesting thing is that some of the properties that we attribute to time, like the sense of how fast it goes, have nothing to do with physics, they have to do with our brain and the way the brain relates to the universe. One has to use neuroscience to understand it. A lot of what we call 'time' in reality is not clock time; it's the fact that with memories – and anticipations – our brain connects to the rest of the world a little bit before and a little bit after, and that creates this complicated structure of memory and anticipation. The beauty of the problem of time is its complexity. All the scientists come in to tell us something that makes up this very rich experience which is our own experience of time.

How does time act in the more extreme places in the universe, such as around a black hole, for example?
If I go close to a black hole, time slows down for me. In fact, it will slow down completely if I get to the [event] horizon, which is essentially the surface of a black hole. This means, for instance, if I could go there – and as I used to say, it's just an issue of money. If we put in enough money to build a spacecraft, we could go there – and then wait a few months in close proximity of the black hole, and then I turn my engine on and I come out, when I come out, I am very much in the future with respect to when I went in.

I could stay there for ten minutes for me, and when I come out, maybe three thousand years have passed. A black hole is a time-slower. It's something that when you go there and you jump to the future, time for you goes extremely slower, while outside it continues faster. That we know very well. That we know for sure is one of the physical effects that allowed us to compute what happens in the proximity of a black hole and predict the image of the black hole that was seen this year.

What don't scientists know?
What we don't know for sure is what happens at the centre of the black hole, because for that you need to know quantum gravity. But the current speculation is that as you enter the black hole you can get to the centre, and it's possible that there is a 'bounce', and very rapidly you are expelled out. This occurs as a black hole becomes a white hole and you come out, and then like what I said before, the effect is much stronger. It takes a few seconds to get to the centre and a few seconds to come out, but you come out very, very far into the future – maybe billions of years!

Is this concept the same as when scientists talk about travelling at speeds close to light?
It's a very similar phenomenon, because when you travel very fast, time also slows down for you. If you were to leave Earth and move at a speed close to the speed of light, you can come back and a short time has passed, while on the Earth a long time has passed.

The two phenomena are related, but are not the same because the first one [travelling close to the speed of light] was already understood by Einstein in 1905 with the effects of special relativity and how the structure of space-time does that. The second one – the one when talking about orbiting a black hole or the Earth – this is due to gravity, so it is nothing that comes from special relativity. Einstein understood that ten years later in 1915, and it is related to the presence of a big mass. The first not being related to the mass. But they are similar, because in both cases there comes something out of the speed at which time passes. One case had to do with velocity, the other being the proximity of a large mass.

> "Time is like an onion: you have to take away layer by layer and understand each one with its own language"

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With regards to space-time, do you think it's possible to move through time the same way we move through space?

Well, our lives are all about moving through time, we are doing it all the time. Just by living we are moving through time. Not only is it possible, but we are doing it all the time. Now, moving faster into the future is possible, as I just told you a way of doing that – go near a black hole and come back and you're in the future. So moving into the future is certainly physically possible, and it is only a matter of engining and money.

However, going into the past is a very different story because the difference between the past and the future has to do with entropy, thermodynamics, statistics and probability. The difference between the past and the future is mainly to do with the probability difference. A phenomenon that can happen in one direction, like a glass that breaks, is very improbable to happen in the other direction – pieces of glass moving together by chance and forming the glass. In a sense, to move back in time you have to beat very high contrary odds. You have to go against probability.

It's not logically impossible, but I don't think we could ever develop the technology capable of doing that. In principle it is not impossible to go to the past, but in practice I don't think you're going to be able to for a long time.

When you're writing a book like this, how hard is it to take these difficult concepts and make it more understandable to the public?

I think first of all, if you understand something well it becomes easier to say. When we are not good at explaining something, it is because we haven't understood it well. You see, if we think about the science of far away past, like Copernicus, when Copernicus wrote his book, it was a very technical book. [It was] very complicated with a lot of strange elements, strange ideas and was incomprehensible.

Now it is completely easy. The Earth spins and goes around the Sun. Basically that's it. We got used to the fact the Earth is moving and when we see the sunset it's not the Sun going down, but it's actually us spinning. So Copernicus' book has been completely digested and we accept the idea that we are actually moving very fast even though we don't feel it, because that is something very well understood.

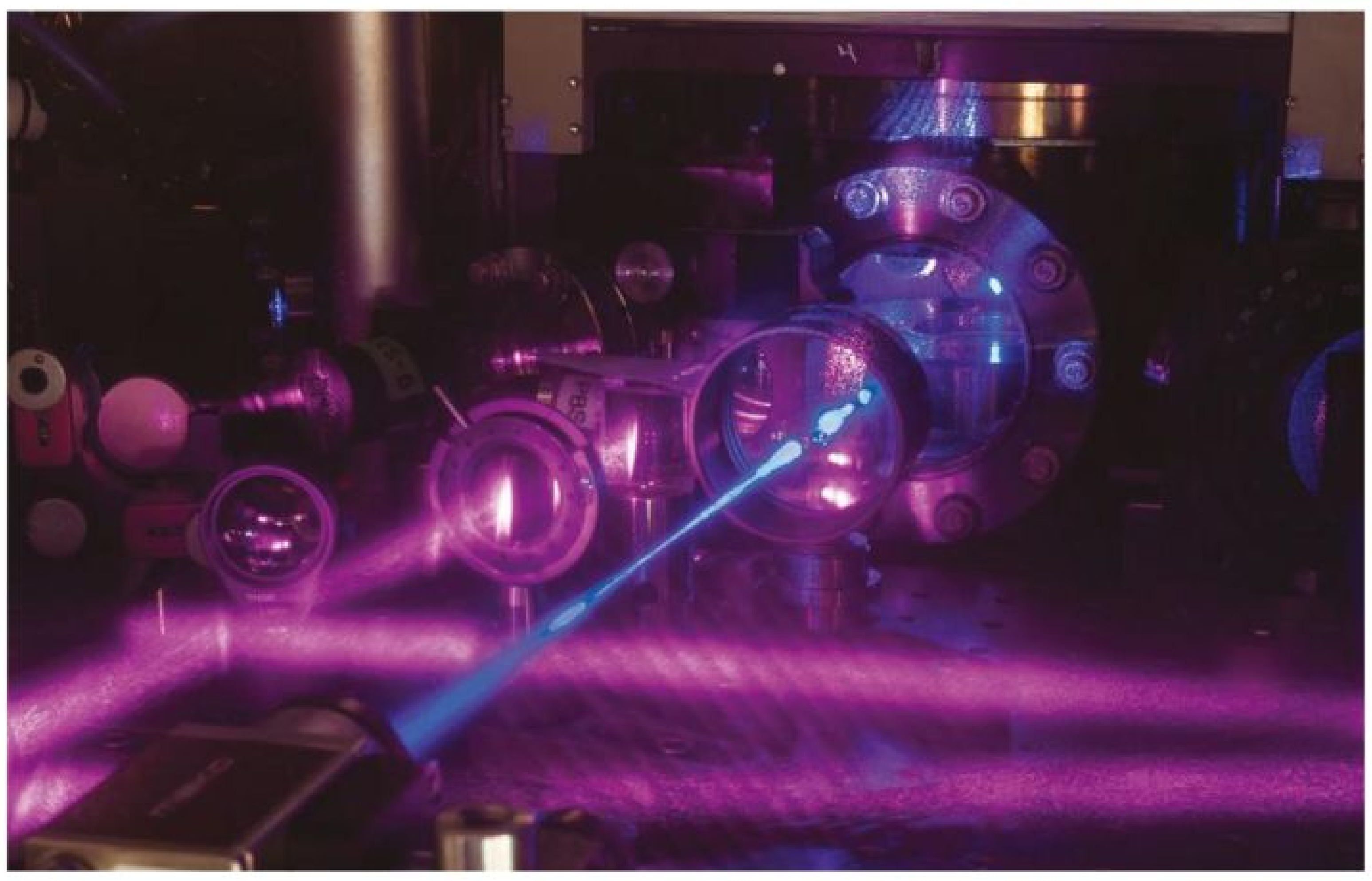
When we try and explain difficult things, like quantum mechanics, it's because we don't yet have clear ideas about quantum mechanics. In order to explain something, one must have digested it very, very well. And the second thing is that I write books for a general audience and not for specialists, and not even for people who are very keen on the subject. There are popularisation books on fundamental physics that are written for people who are very keen on that, so they have a lot of detail. I try to take away the details, give as few details as possible, and always zoom in to the key idea and try to explain as clearly as I can the central theme that is understood. Not the why, the how or the details. Just the core.

Are there any experiments coming up that you are looking forward to and think could explain such mysteries?

Until not long ago, I had two dreams. One is that gravitational waves are detected and the other that we could see a black hole. But this has happened! It's fantastic! I am now working on the future of black holes. What happens inside the black holes and how they transform in the future, and we're working with this possibility that black holes transform into white holes. So my dream now is to see effects of this black-to-white transformation and see some astrophysical signal that could confirm that this happens.

Right: Time is 'wrong' if we make it universal

Below: Atomic clocks are used to measure the fine differences in time at different altitudes



MYSTERIES OF THE UNIVERSE

WHERE DO BLACK HOLES LEAD?

If you could journey through the cosmos' most monstrous objects, what tales – if any – would you be able to tell?

Reported by David Crookes

So there you are, about to leap into a black hole. What could possibly await should – against all odds – you somehow survive? Where would you end up and what tantalising tales would you be able to regale if you managed to clamour your way back?

The simple answer to all of these questions is, as Professor Richard Massey explains, "Who knows?" As Royal Society research fellow at the Institute for Computational Cosmology at Durham University, he is fully aware that the mysteries of black holes run deep. "Falling through an event horizon is literally passing beyond the veil – once someone falls past it, nobody could ever send a message back," he says. "They'd be ripped to pieces by the enormous gravity, so I doubt anyone falling through would get anywhere."

If that sounds like a disappointing – and painful – answer, then it is to be expected. Ever since Albert Einstein's general theory of relativity was considered to have predicted black holes by linking space-time with the action of gravity, it has been

© Illustration by Tobias Roetsch

Right: An artist's impression of a tidal disruption event which occurs when a star passes too close to a supermassive black hole

> “Black holes should be redefined as metastable bound states of the gravitational field” **Stephen Hawking**

known that black holes result from the death of a massive star leaving behind a small, dense remnant core. Assuming this core has more than roughly three-times the mass of the Sun, gravity would overwhelm to such a degree that it would fall in on itself into a single point, or singularity, understood to be the black hole's infinitely dense core.

The resulting uninhabitable black hole would have such a powerful gravitational pull that not even light could avoid it. So should you then find yourself at the event horizon – the point at which light and matter can only pass inward, as proposed by the German astronomer Karl Schwarzschild – there is no escape. As Massey says, tidal forces would reduce your body into strands of atoms – or ‘spaghettification’, as it is also known – and the object would eventually end up crushed at the singularity. The idea that you could pop out somewhere – perhaps at the other side – seems utterly fantastical.

Or is it? Over the years scientists have looked into the possibility that black holes could be wormholes to other galaxies. They may even be, as some have suggested, a path to another universe.

Such an idea has been floating around for some time: Einstein teamed up with Nathan Rosen to theorise bridges that connect two different points in space-time in 1935. But it gained some fresh ground in the 1980s when physicist Kip Thorne – one of the world's leading experts on the astrophysical implications of Einstein's general theory of relativity – raised a discussion about whether objects could physically travel through them.

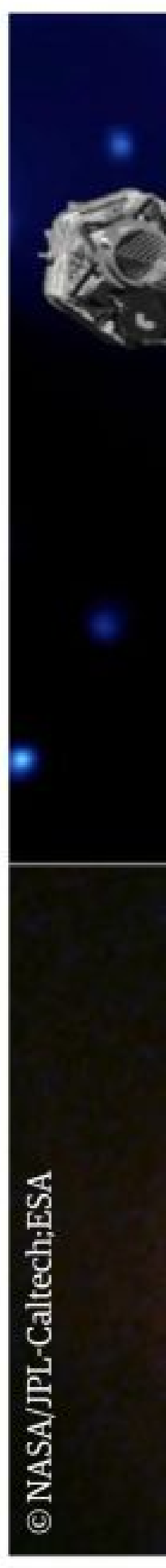
“Reading Kip Thorne's popular book about wormholes is what first got me excited about physics as a child,” says Massey. “But the only details I can remember are that stable, traversable wormholes are very unlikely to exist. To stop a wormhole instantly collapsing into an ordinary black hole, you need a ring of some weird matter that has less than zero mass and therefore repulsive gravity. And even if this type of matter happens to be manufacturable, shaping it into a ring then needs either a huge amount of luck straight after the Big Bang, or some very advanced aliens.”

Indeed, Thorne, who lent his expert advice to the production team for the Hollywood movie *Interstellar*, wrote: “We see no objects in our universe that could become wormholes as they age,” in his 2014 book *The Science of Interstellar*. He also told our sister publication, space.com, that journeys through these theoretical tunnels would most likely remain science fiction, and there is certainly no firm evidence that a black hole could allow for such a passage.

We can't get up close to see for ourselves. Why, we can't even take photographs of anything that takes place inside a black hole – if light cannot escape their huge gravity, then nothing can be snapped by a camera. As it stands, theory suggests that anything which does go beyond the event horizon is simply added to the black hole and, what's more, because time distorts close to this boundary, this will appear to take place incredibly slowly, so answers won't be quickly forthcoming – to a distant observer, clocks that are near a black hole would appear to tick less fast than one further away.

“I think the standard story is that they lead to the end of time,” says Douglas Finkbeiner, professor of astronomy and physics at Harvard University. “An observer far away will not see their astronaut friend fall into the black hole. They'll just get redder and fainter as they approach the event horizon [as a result of gravitational red shift]. But the friend falls right in, to a place beyond 'forever'. Whatever that means.”

Certainly, if black holes do lead to another part of a galaxy or another universe, there would need to be something opposite to them on the other side. Could this be a white hole – a theory put



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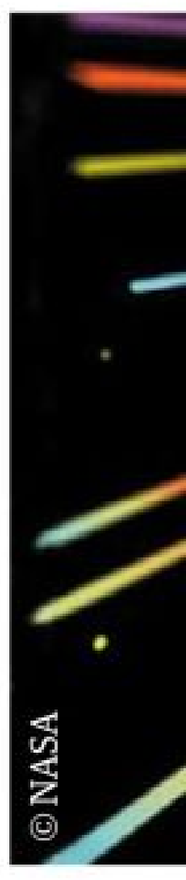

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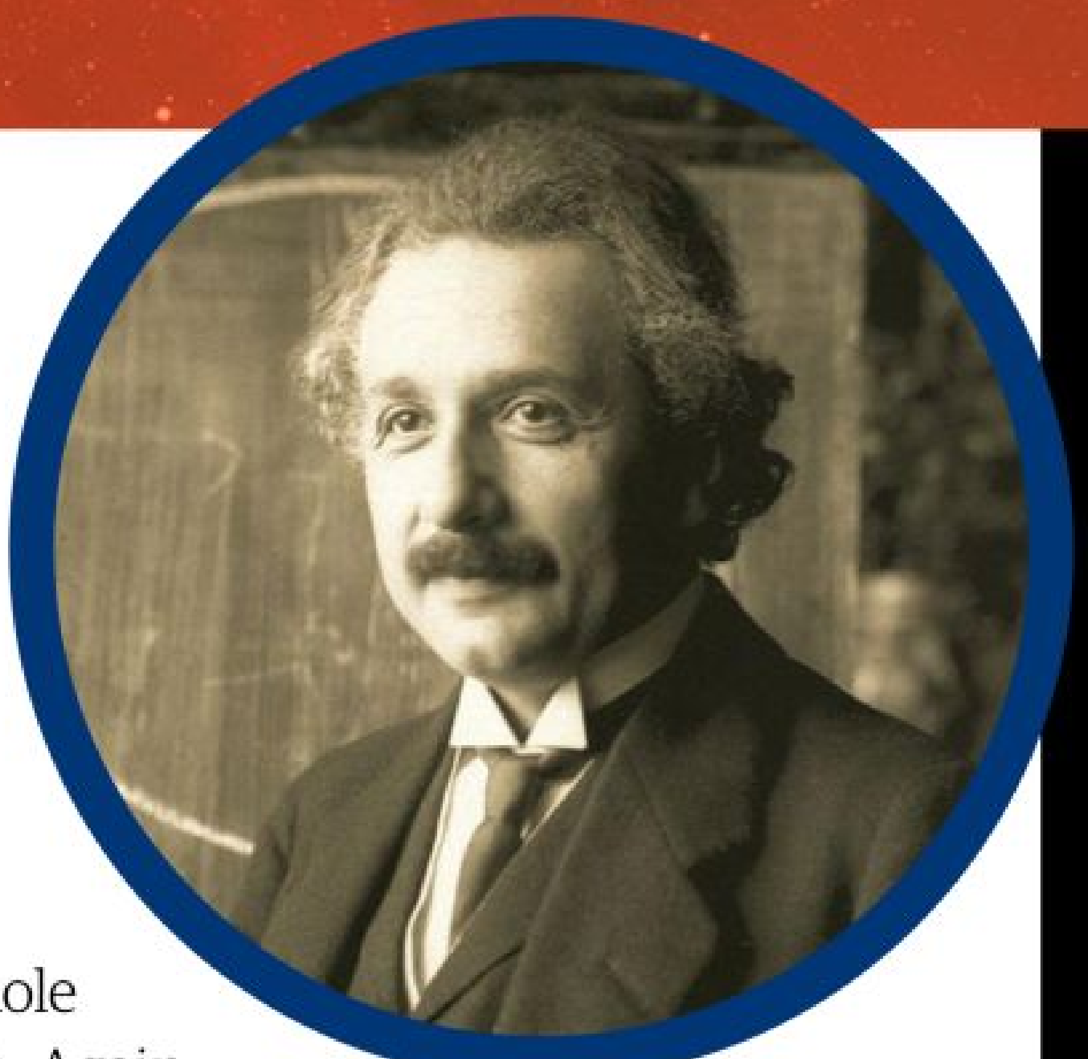


forward by Russian cosmologist Igor Novikov in 1964? Novikov proposed that a black hole links to a white hole that exists in the past. Unlike a black hole, a white hole will allow light and matter to leave. Again, unlike black holes, light and matter will not be able to enter.

White holes were said to be evident in mysterious invisible radio sources, first spotted by Maarten Schmidt, a Caltech astronomer working at Palomar Observatory. In 1963 he discovered a distant object some 2 billion light years away which was shining so bright that it was actually greater than the Milky Way in its entirety. The object – 3C 273 – was subsequently referred to as a quasi-stellar radio source, or quasar, and there were later suggestions that quasars were, in fact, openings of these proposed white holes.

Very few scientists today believe white holes are quasars. But a potential connection between black and white holes is still being explored. Carlo Rovelli and Hal M. Haggard wrote a paper in 2014 which claimed to "show that there is a classic metric satisfying the Einstein equations outside a finite space-time region where matter collapses into a black hole and then emerges from a while hole". In other words, all of the material black holes have swallowed could be spewed out, and black holes may become white holes when they die.

Far from destroying the information that it absorbs, the collapse of a black hole would be halted. It would instead experience a quantum

Above Albert Einstein's general theory of relativity provides the foundation for the current understanding of black holes

Far bottom left: NASA's Nuclear Spectroscopic Telescope Array (NuSTAR) is conducting a deep survey for black holes

Above: Could wormholes formed from black holes – if they exist – allow travel from one part of the galaxy to another?

The theories

Where do scientists believe information plunged into a black hole may end up?

General relativity

It still holds that our best theory of gravity is the one that Einstein came up with more than 100 years ago. It predicts locations where space-time ends and gravity becomes infinite – the point of singularity. Gravitational forces beyond the event horizon cause spaghettification and eventual crushing. Information is lost forever.

Loop quantum gravity

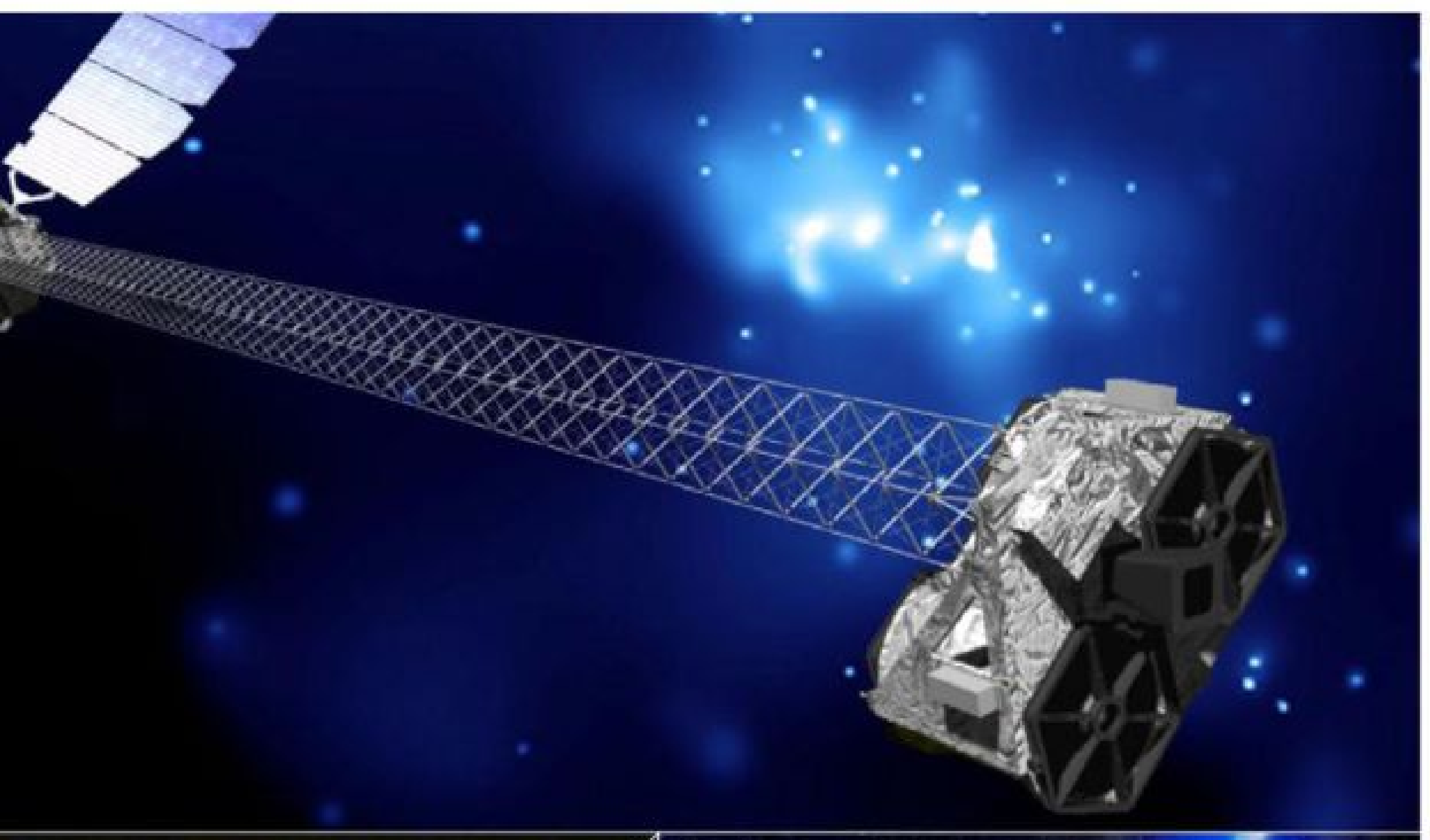
LQG merges quantum mechanics and general relativity and seeks to show that singularities cannot exist. Instead, the theory predicts that a funnel exists that leads to another branch of the space-time, perhaps creating an entry point to another universe. It means information is not lost and merely ends up elsewhere.

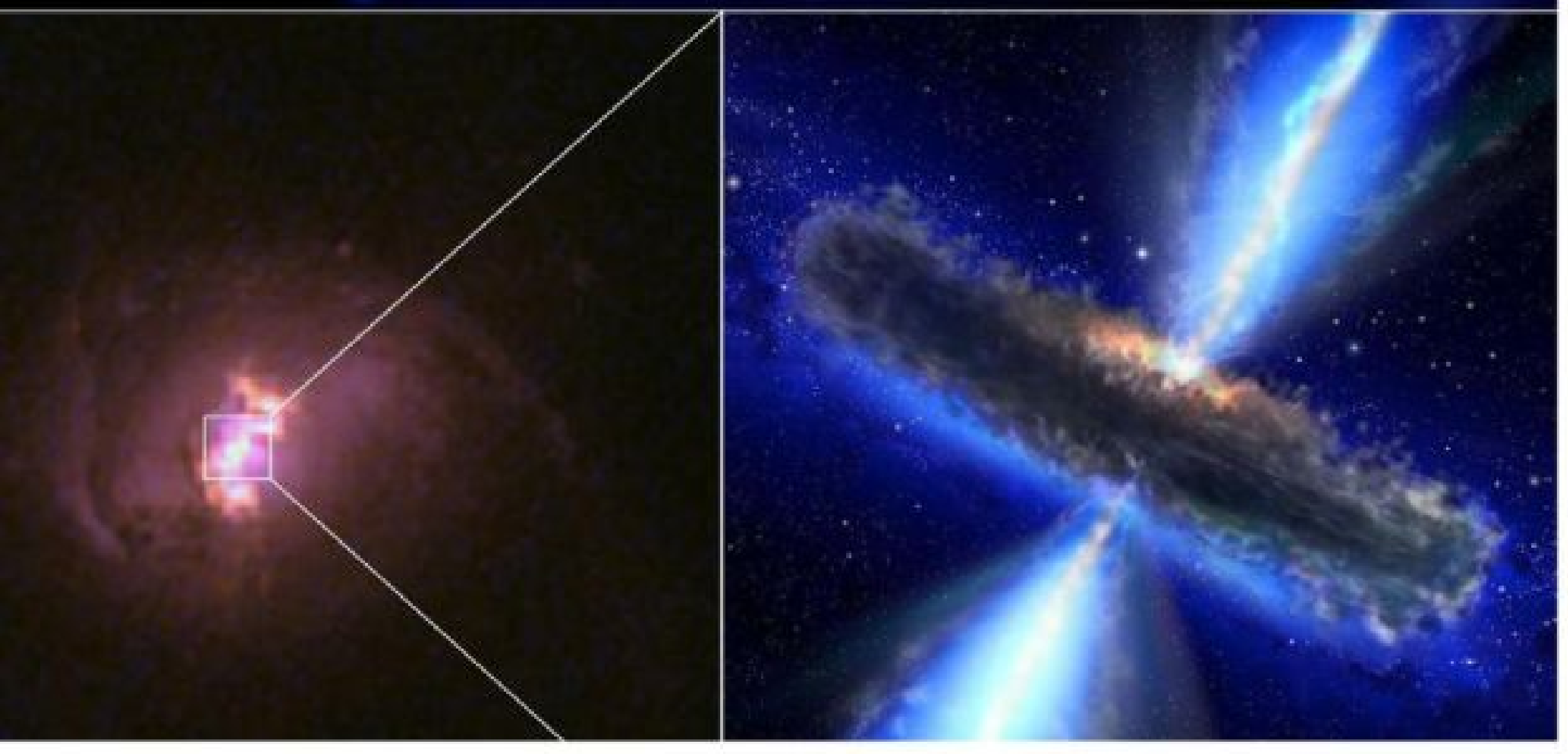
Black holes disappear

Stephen Hawking suggested in 1974 that black holes eventually evaporate. They emit particles – or Hawking radiation – which eventually causes enough energy and mass to be lost. Earlier this year physicists tested this theory in a lab using Bose-Einstein concentrate made of gas and particles cooled to near absolute zero. It found what was captured would trickle away.

No-hair theorem debunked

Hawking's theory still suggested that most of the information that fell into a black hole would be erased: only details of the mass, charge and angular momentum would survive. But string theory suggested information cannot be lost. Hawking and other scientists found black holes have 'soft hair' – low-energy quantum excitations which release information when black holes evaporate.





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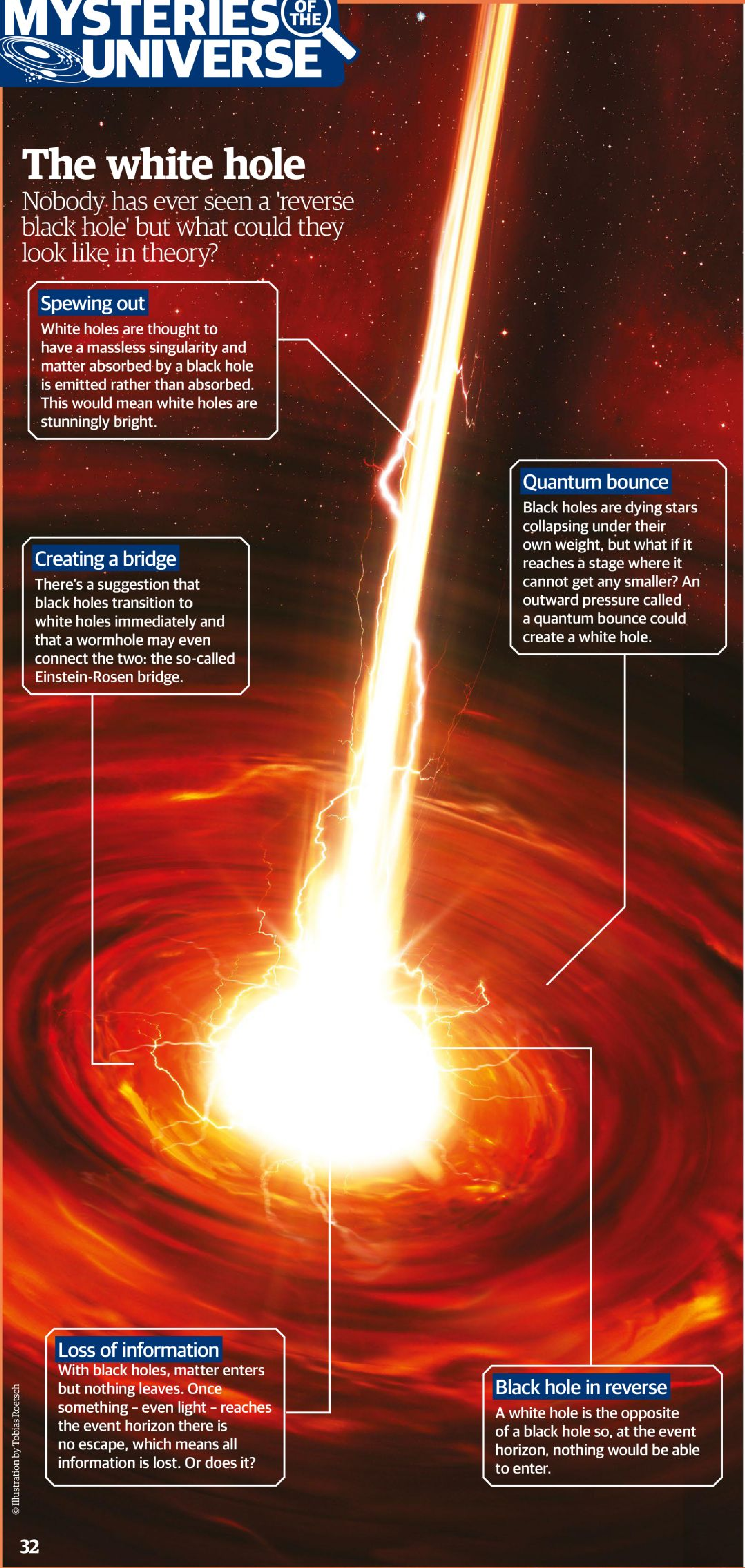
The white hole

Nobody has ever seen a 'reverse black hole' but what could they look like in theory?



Spewing out

White holes are thought to have a massless singularity and matter absorbed by a black hole is emitted rather than absorbed. This would mean white holes are stunningly bright.

Creating a bridge

There's a suggestion that black holes transition to white holes immediately and that a wormhole may even connect the two: the so-called Einstein-Rosen bridge.

Quantum bounce

Black holes are dying stars collapsing under their own weight, but what if it reaches a stage where it cannot get any smaller? An outward pressure called a quantum bounce could create a white hole.

Loss of information

With black holes, matter enters but nothing leaves. Once something – even light – reaches the event horizon there is no escape, which means all information is lost. Or does it?

Black hole in reverse

A white hole is the opposite of a black hole so, at the event horizon, nothing would be able to enter.

© Illustration by Tobias Roetsch

bounce, allowing information to escape. Should this be the case, it would shed some light on a proposal by former Cambridge University cosmologist and theoretical physicist Stephen Hawking who, in the 1970s, explored the possibility that black holes emit particles and radiation – thermal heat – as a result of quantum fluctuations.

"Hawking said a black hole doesn't last forever," explains Finkbeiner. Indeed, the acclaimed scientist calculated that the radiation would cause a black hole to lose energy, shrink and disappear in a paper published in 1976, called *The Breakdown of Predictability in Gravitational Collapse*. Given his claims that the radiation emitted would be random and contain no information about what had fallen in, the black hole, upon its explosion, would mean masses of information being forever erased.

This put it at odds with quantum theory, which says information can't be destroyed. Physics states information just becomes more difficult to find because, should it become lost, it becomes impossible to know the past or the future. Hawking's idea led to the 'black hole information paradox' and it has long puzzled scientists. Some have said Hawking was simply wrong, and the man himself even declared he had made an error during a scientific conference in Dublin in 2004.

So does that back the concept of black holes emitting preserved information and throwing it back out via a white hole? Maybe. Jorge Pullin at Louisiana State University and Rodolfo Gambini at the University of the Republic in Montevideo, Uruguay, applied loop quantum gravity to a black hole in 2013 and found that gravity increased towards the core but reduced and plonked whatever was entering into another region of the universe, lending extra credence to the idea of black holes serving as a portal.

> "Falling through an event horizon is passing beyond the veil -nobody could send a message back" **Richard Massey**

In this study singularity does not exist, and so it doesn't form an impenetrable barrier that ends up crushing whatever it encounters. It also means that information doesn't disappear.

Yet physicists Ahmed Almheiri, Donald Marolf, Joseph Polchinski and James Sully still believed Hawking could have been on to something. They worked on a theory that became known as the AMPS firewall or the black hole firewall hypothesis. By their calculations, quantum mechanics could feasibly turn the event horizon into a giant wall of fire and that anything coming into contact would burn in an instant. In that sense, black holes lead nowhere because nothing could ever get inside.

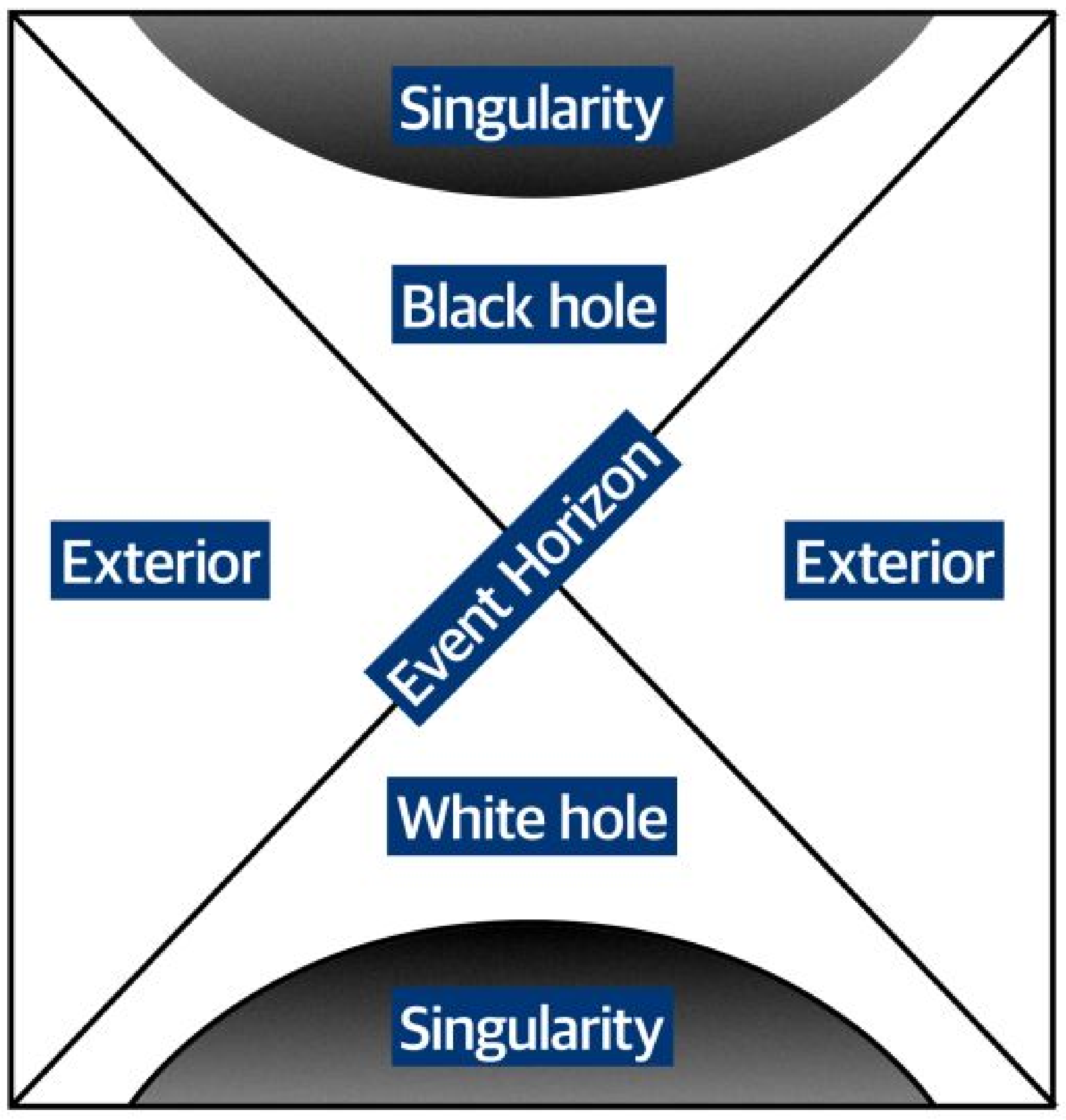
This, however, violates Einstein's general theory of relativity. Someone crossing the event horizon shouldn't actually feel any great hardship because an object would be in free fall and, based on the equivalence principle, that object – or person – would not feel the extreme effects of gravity. It should follow the laws of physics present elsewhere in the universe, but even if it didn't go against Einstein's principle it would undermine quantum field theory or suggest information can actually be lost. Scientists sought a viable explanation.

Step forward Hawking once more. In 2014 he wrote a paper called *Information and Weather Forecasting for Black Holes* in which he eschewed the existence of an event horizon – meaning there is nothing there to burn – saying gravitational collapse would produce an 'apparent horizon' instead.

This horizon would suspend light rays trying to move away from the core of the black hole, and would persist for a 'period of time'. In his rethinking apparent horizons temporarily retain matter and energy before dissolving and releasing them later down the line. The explanation best fits with quantum theory – which says information can't be destroyed – and, if it was ever proven, it suggests that anything could escape from a black hole.

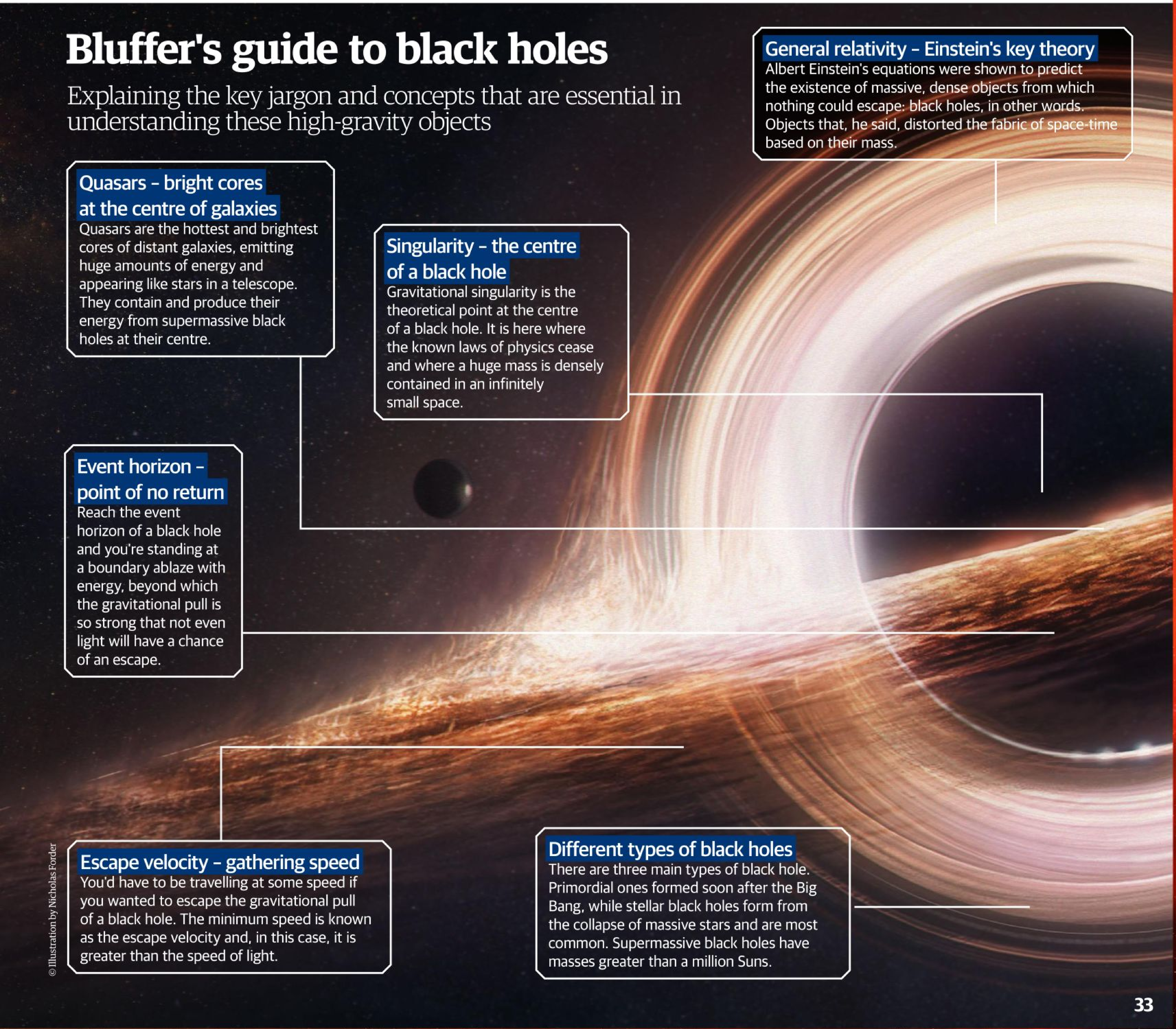
Hawking went as far as saying black holes may not even exist. "Black holes should be redefined as metastable bound states of the gravitational field," he wrote. There would be no singularity, and while the apparent field would move inwards due to gravity, it would never reach the centre and be consolidated within a dense mass.

And yet anything which is emitted will not be in the form of the information swallowed. It would not be possible to figure out what went in by looking at



Bluffer's guide to black holes

Explaining the key jargon and concepts that are essential in understanding these high-gravity objects



General relativity – Einstein's key theory
Albert Einstein's equations were shown to predict the existence of massive, dense objects from which nothing could escape: black holes, in other words. Objects that, he said, distorted the fabric of space-time based on their mass.

Quasars – bright cores at the centre of galaxies
Quasars are the hottest and brightest cores of distant galaxies, emitting huge amounts of energy and appearing like stars in a telescope. They contain and produce their energy from supermassive black holes at their centre.

Singularity – the centre of a black hole
Gravitational singularity is the theoretical point at the centre of a black hole. It is here where the known laws of physics cease and where a huge mass is densely contained in an infinitely small space.

Event horizon – point of no return
Reach the event horizon of a black hole and you're standing at a boundary ablaze with energy, beyond which the gravitational pull is so strong that not even light will have a chance of an escape.

Escape velocity – gathering speed
You'd have to be travelling at some speed if you wanted to escape the gravitational pull of a black hole. The minimum speed is known as the escape velocity and, in this case, it is greater than the speed of light.

Different types of black holes
There are three main types of black hole. Primordial ones formed soon after the Big Bang, while stellar black holes form from the collapse of massive stars and are most common. Supermassive black holes have masses greater than a million Suns.

© Illustration by Nicholas Forder

what is coming out, which causes problems of its own – not least for, say, a human who ever found themselves in such an alarming position… they'd never feel the same again!

One thing's for sure, this particular mystery is going to swallow up many more scientific hours for a long time to come. Rovelli and Francesca Vidotto recently suggested a component of dark matter could be formed by remnants of evaporated black holes, and Hawking's paper on black holes and 'soft hair' was released in 2018 which describes information about particles being left around the point of no return, the event horizon – an idea that shows information is not lost but captured.

This flew in the face of the no-hair theorem which was expressed by physicist John Archibald Wheeler and worked on the basis that two black holes would be indistinguishable to an observer because none of the special particle physics pseudo-charges would be conserved. It's an idea that has got scientists talking, but there is some way to go before it's seen as the answer for where black holes lead. If only we could find a way to leap into one.

Event Horizon Telescope

The EHT is the first-ever experiment to capture an image of a black hole

On the lookout

The EHT has focused on SgrA*, the black hole at the centre of the Milky Way, as well as M87 in the Virgo constellation. Eight telescopes were recently connected to peer at M87. Together they acted like the curved surface of a mirror reflecting light to a central point – only they do so virtually.

Collecting data

The information collected is stored on hard disks which are then physically sent to a central processing department where they're combined and run through a super computer. The combination of the data forms an image using algorithms.

Getting up close

The observatories combine to create a virtual telescope the size of Earth. Such a large interferometer is needed because the black holes – despite their size – appear tiny when viewed from our planet.

Network of telescopes

The Event Horizon Telescope (EHT) is an international collaboration that links radio dishes around Earth, such as this one located on Pico Veleta in Andalucia, Spain.

Remaining stable

The idea has been to take a picture of the event horizon since the black hole itself is too dark. The dishes collect the millimetre-wavelength radio waves and need to be perfectly synced so that their recordings can be aligned. For this they use atomic clocks.

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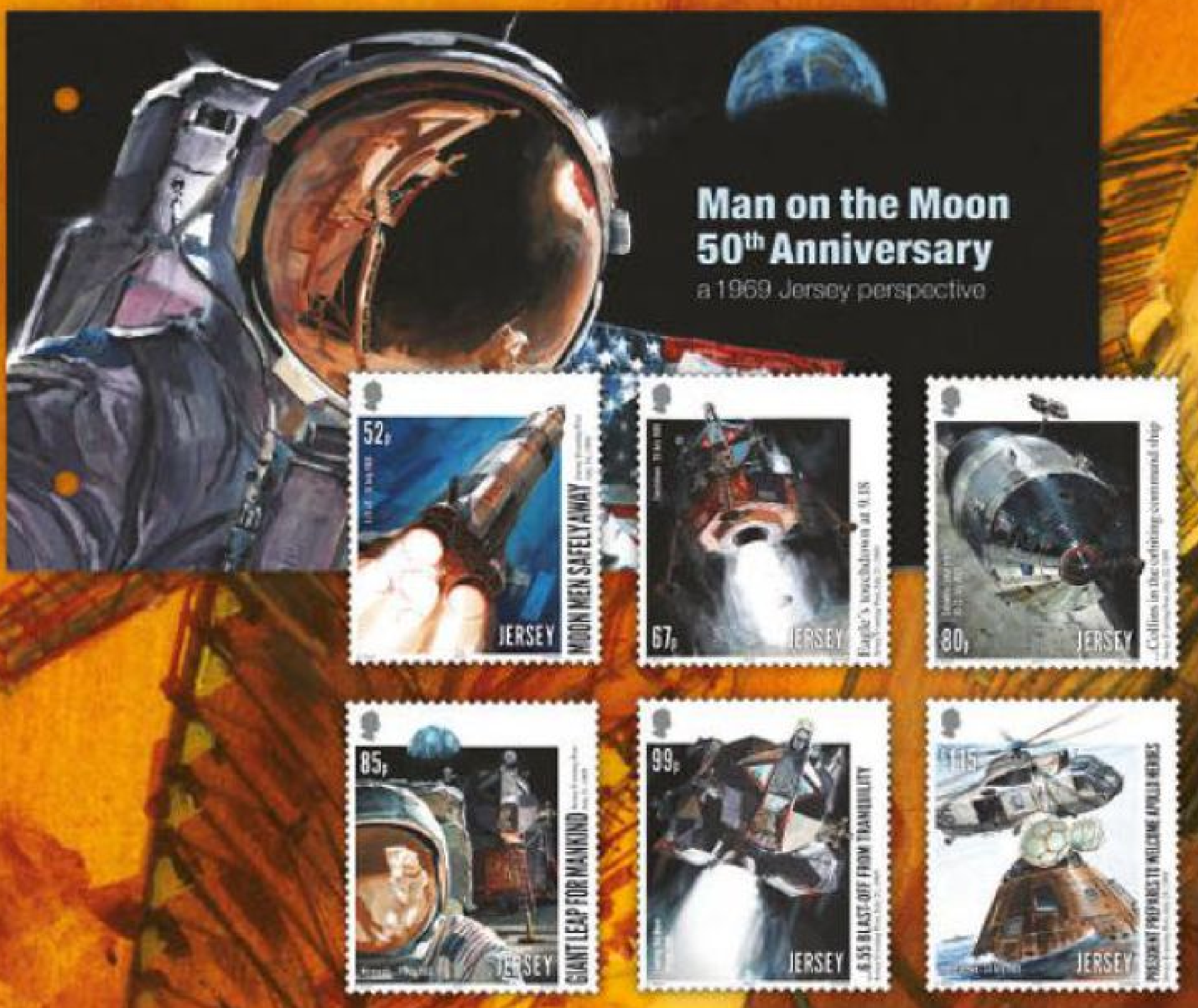

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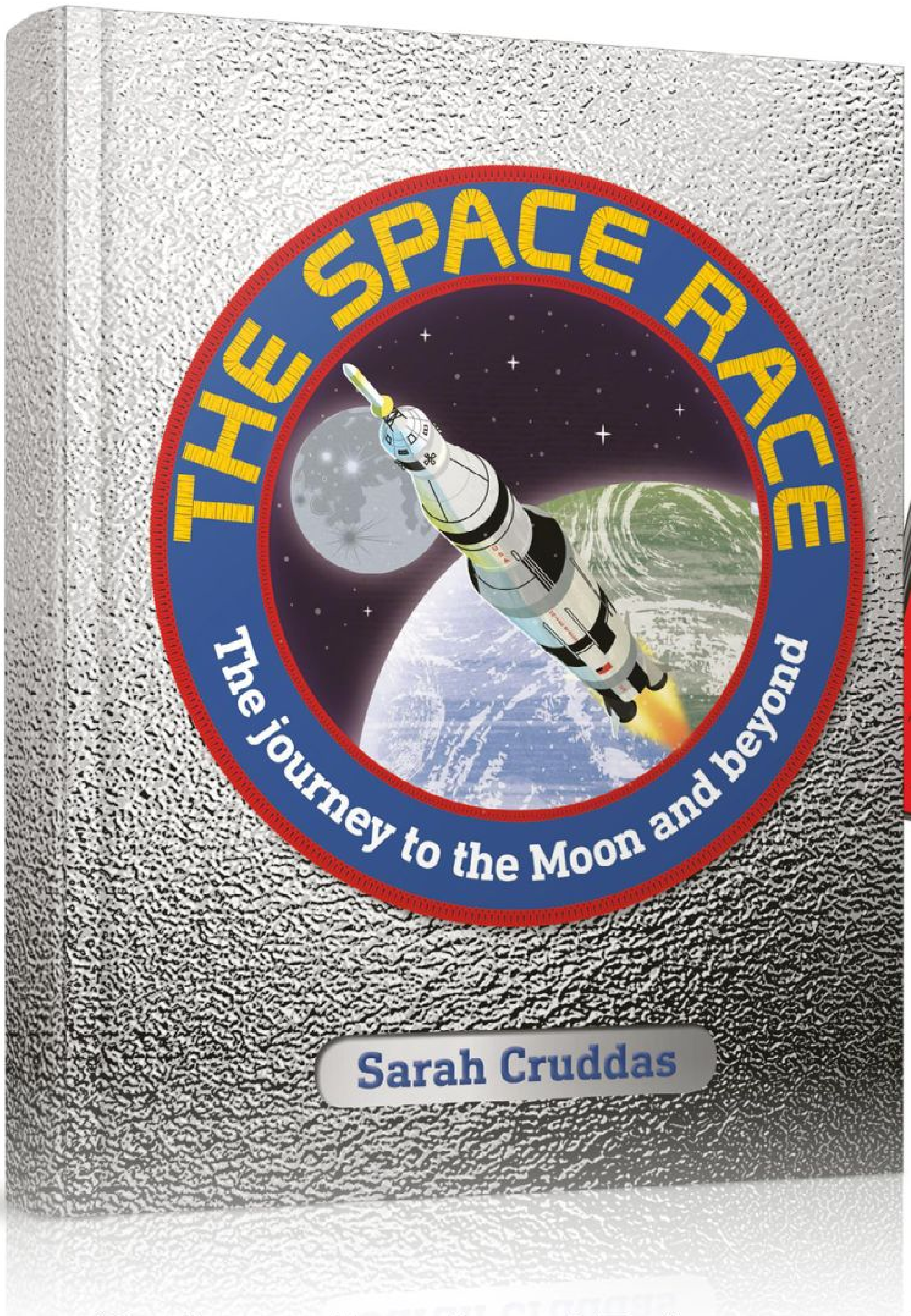

THE SPACE RACE

The journey to the Moon and beyond

Sarah Cruddas

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Valentina Tereshkova

While the United States set its sights on reaching the Moon, the Soviet Union continued to set new records in spaceflight. On 16 June 1963, cosmonaut Valentina Tereshkova became the first woman to travel to space.

Valentina spent three days orbiting the Earth alone in her Vostok capsule. Her call sign, which she used to identify herself on radio transmissions, was *Chayka*, meaning "Seagull". Back home, people watched video footage of her smiling with her log book floating in front of her.

Her spaceflight was part of a duel mission. Another cosmonaut, Valery Bykovsky, had travelled in a separate capsule that launched two days earlier.

The mission was a dream come true for Valentina, who was already a skilled parachute jumper. She returned to Earth a global icon, and later gained a doctorate in engineering.

Training for space

It took 18 months for Valentina to be ready for her spaceflight. She had to undergo lots of training, including tests to see how well she would cope with being on her own in space.

Valentina was wired up to machines for health checks.

This spinning frame (gyroscope) produced a sensation similar to tumbling in space.

Valentina studied engineering to learn how space rockets worked.

35

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Dwarf Planet Profile

Pluto

The dwarf planet in the realms of the Kuiper Belt is not just a barren ball of rock and ice

Pluto is arguably the most famous of all the dwarf planets, with many still fighting in its corner to get back its status as a planet. It resides in the darkest depths of the Solar System, the Kuiper Belt, 5.9 billion kilometres (3.7 billion miles) away from the Sun, which is roughly 40-times the Earth-Sun distance. The original member of the nine planets of the Solar System was discovered in 1930 by an American astronomer by the name of Clyde Tombaugh. Although Tombaugh discovered the dwarf planet, the credit for naming Pluto goes to an 11-year-old girl from Oxford, England, called Venetia Burney. She suggested that the then-planet be named after the Roman god of the underworld, which can't be far off the same conditions as the Kuiper Belt – dark, lonely and unbearably cold, with temperatures reaching as low as -240 degrees Celsius (-400 degrees Fahrenheit).

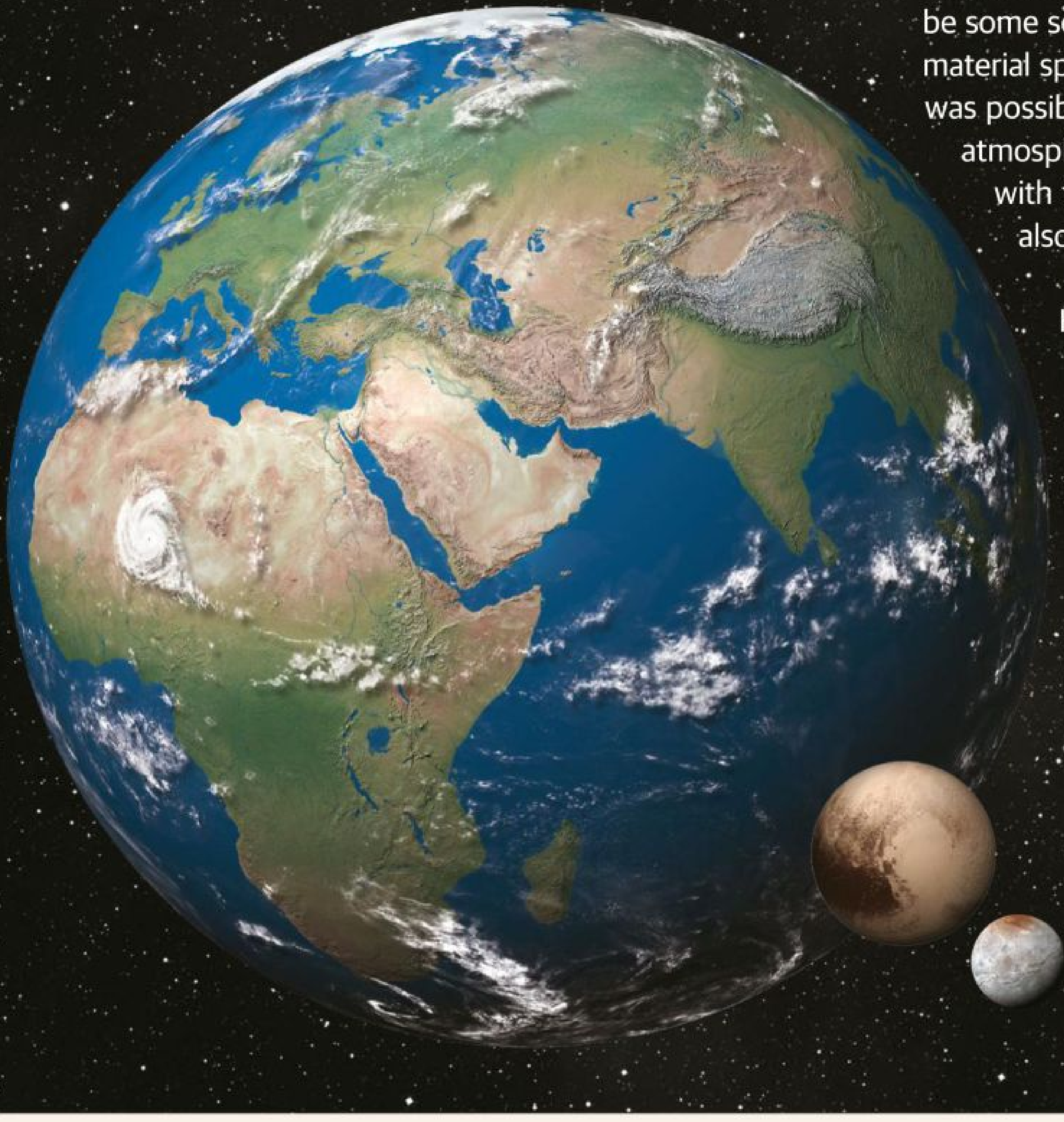
Its enormous distance from the Sun leads to Pluto having an equally enormous year – it takes 248 Earth years to complete one orbit. To put that into context, if Pluto completed an orbit this year, then when it started that orbit no one would have had a clue about Pluto, and French astronomer Charles Messier would have still been in the process of constructing the famous Messier Catalogue of deep-sky objects.

Pluto saw its declassification to a dwarf planet in 2006 when the International Astronomical Union defined the criteria of a planet, with Pluto just falling short. It is only a small world: it is roughly 2,400 kilometres (1,500 miles) wide, making it about two-thirds the size of the Moon and half the width of the United States. Although Pluto had been observed by many ground-based telescopes, and even NASA/ESA's Hubble Space Telescope, its true form and physical characteristics weren't apparent until it had its one-and-only flyby by NASA's New Horizons spacecraft, launched in 2006.

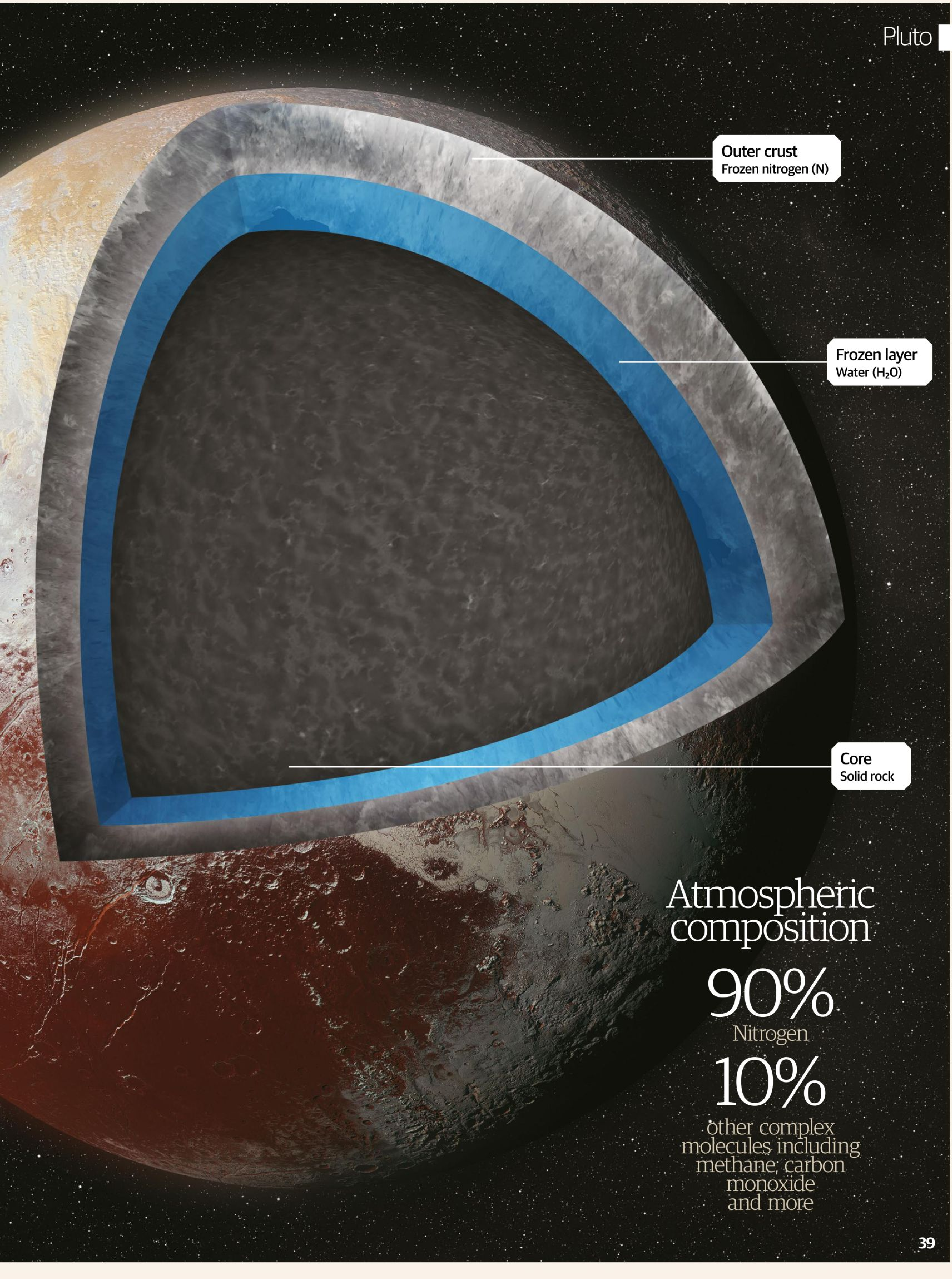
After the flyby in 2015 the surface of Pluto came into marvellous resolution, and many people of Earth marvelled at its beauty. "The complexity of the Pluto system – from its geology to its satellite system to its atmosphere – has been beyond our wildest imagination," says Alan Stern, New Horizons principal investigator from the Southwest Research Institute in Boulder, Colorado, United States. "Everywhere we turn are new mysteries."

When astronomers first observed the surface they noticed a host of mountains, valleys, plains and craters, but the plains of frozen nitrogen gas exhibit very few craters, meaning that there must be some sort of surface replenishment – possibly material spraying from a subsurface ocean. All of this was possible to see with Pluto's virtually nonexistent atmosphere that consists of molecular nitrogen, with traces of methane and carbon monoxide also having been detected.

Pluto has five known moons: Charon, Nix, Hydra, Kerberos and Styx. These moons were likely formed as the result of a collision between Pluto and an object of similar size billions of years ago. Charon is the largest of these moons and is about half the size of Pluto, making it the largest moon relative to its host. In fact, the Pluto-Charon double act can sometimes be referred to as a double planet system.



Pluto and its main moon Charon compared against Earth



Atmospheric composition

90%
Nitrogen

10%
other complex molecules including methane, carbon monoxide and more

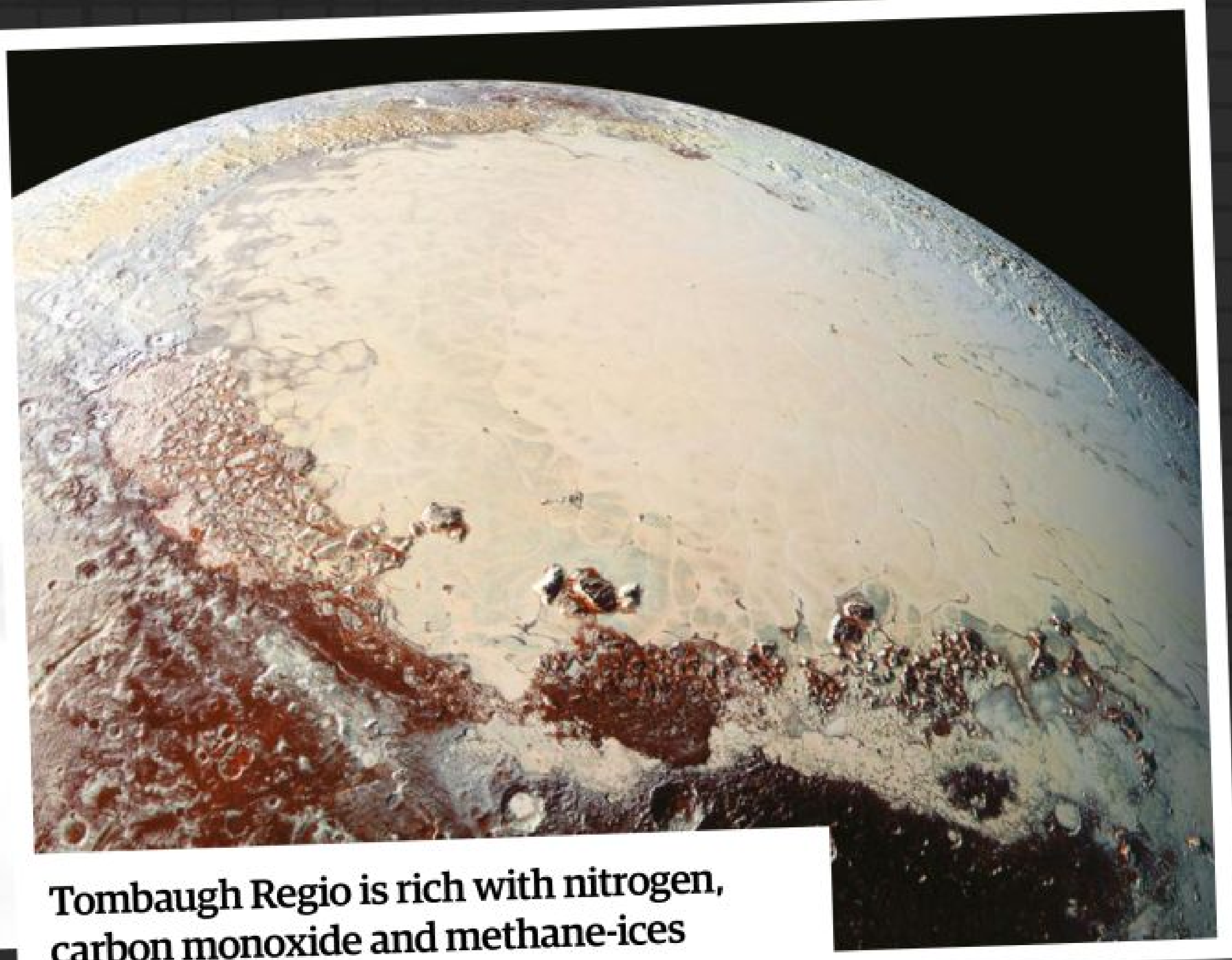
© NASA; Tobias Roetsch

Pluto catch-up

Warming the heart of Pluto

When New Horizons flew past Pluto in 2015, it shattered perceptions of a dull, rocky ball and opened astronomers' eyes to the idea this could be an active world. On its flyby the spacecraft revealed a heart-shaped region in the northern hemisphere of the dwarf planet known as Tombaugh Regio. After studying data on this region, astronomers have found evidence for a subsurface ocean existing under the layer of nitrogen ice.

"This could mean there are more oceans in the universe than previously thought, making the existence of extraterrestrial life more plausible," says Shunichi Kamata of Hokkaido University in Japan. This study suggests that there is a layer of gas hydrates – ice-like solids composed of gases trapped in molecular water – that insulates that region of Pluto, which prevents freezing within its interior. Ocean worlds are an exciting area of research in the Solar System because it means that one of the fundamental needs for life is abundant beyond our home planet. It could mean that extraterrestrial life could exist elsewhere in the Solar System.



Tombaugh Regio is rich with nitrogen, carbon monoxide and methane-ices

Pluto was considered a planet until 2006

Re-opening the planetary discussion

29 April 2019 saw an informal vote about whether Pluto should be reinstated as a planet or remain a dwarf planet. This vote saw the inclusion of experts on the matter, including NASA's New Horizons principal investigator Alan Stern and the former president of the International Astronomical Union (IAU) Ron Ekers.

It was the IAU that stripped Pluto of its planetary status in 2006. One of the main criteria that denotes a planet was it having "cleared the neighbourhood around its orbit", but as Pluto crosses the orbit of Neptune it did not meet this requirement. This decision was made after a long-winded process of deciding what should define a planet by the IAU, but sadly Pluto did not reach said criteria, argued Ekers.

When Stern took to the stage, he argued that Pluto is much more of a world – with oceans, mountains and glaciers just to name some features – and that it is much harder to clear an orbit in the region beyond Neptune than it is closer to the Sun. After the debate a vote was taken; 30 people voted in favour of keeping Pluto as a dwarf planet, whereas a whopping 130 voted in favour of Pluto being a planet.

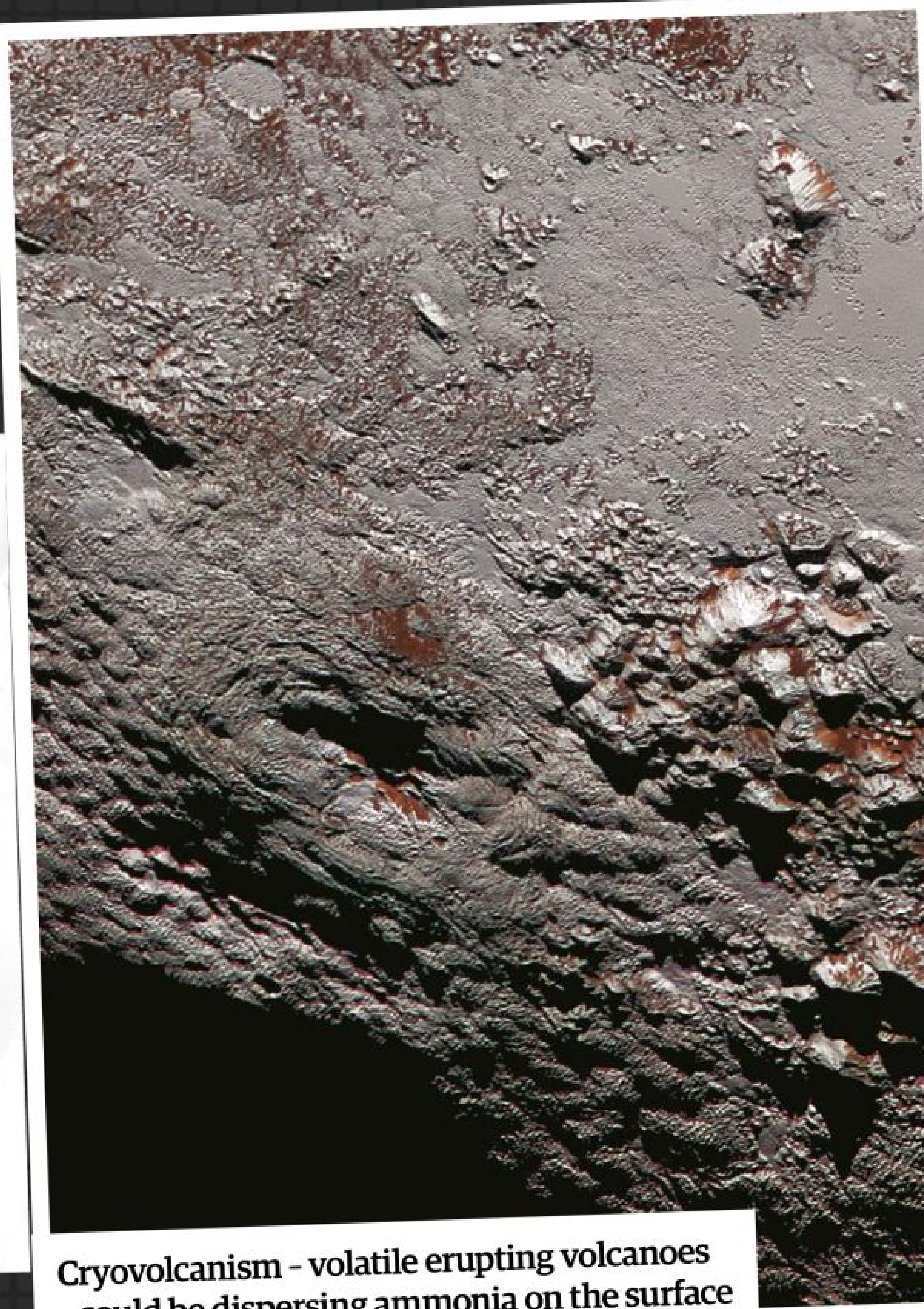
> "The complexity of the Pluto system has been beyond our wildest imagination. Everywhere we turn are new mysteries"

Ammonia makes Pluto look younger

Ammonia – a nitrogen atom with three hydrogen atoms branching off – is a building block of life and a welcome sight to astronomers. As ammonia is a key compound for life as we know it, when it is seen on other planets or other bodies, it ticks an important box when looking for what makes a world habitable. Obviously Pluto has many things going against it in terms of habitability – its tiny size, its huge distance from the Sun, relatively no atmosphere and so on – but ammonia is enough to gain the attention of many astrobiologists.

This compound, however, is short-lived on such an exposed body. In the words of Cristina Dalle Ore, a planetary scientist at NASA's Ames Research Center in Moffett Field, California, United States, ammonia "is a fragile molecule and gets destroyed by ultraviolet irradiation as well as cosmic rays. Therefore, when found on a surface it implies that it had been emplaced there relatively recently, some million years before."

Therefore there must be some form of geological activity depositing ammonia onto the surface. Whether there is recent volcanic activity, active vents or whatever gateway there may be between the surface and the potential subsurface ocean, astronomers are now determined to find out how ammonia is getting to the surface to make Pluto look younger.



Cryovolcanism – volatile erupting volcanoes – could be dispersing ammonia on the surface

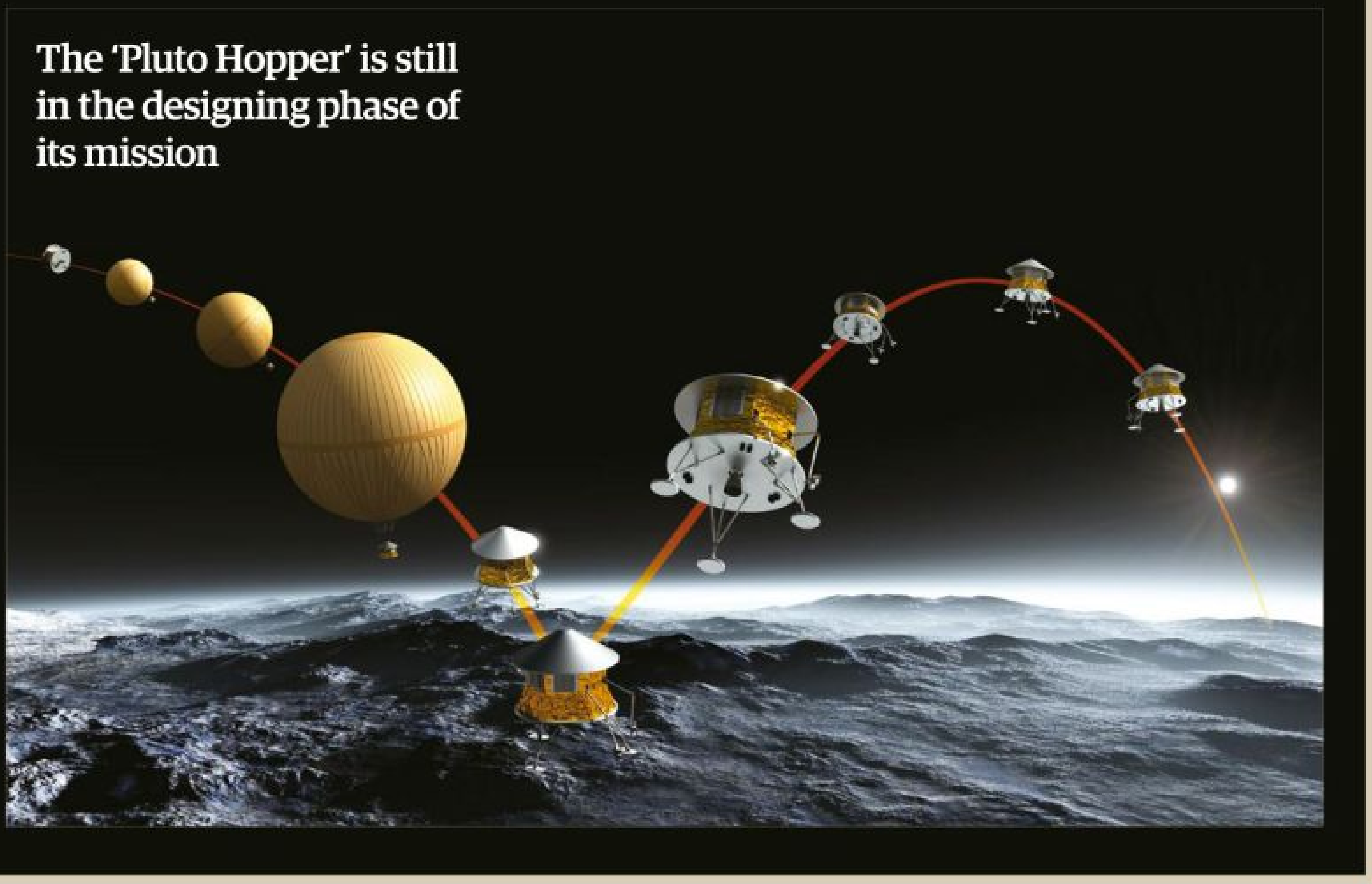
Exploring the past and future of Pluto

Due to the enormous distance to Pluto, exploration has been minimal. For a long time any observations relied on Earth-based telescopes, particularly Hubble, which produced the highest resolution maps of the dwarf planet in 2002 to 2003.

NASA, however, deemed this not quite good enough, choosing to send a space probe to Pluto and see what it was all about. New Horizons was the project chosen to do so and was launched on 19 January 2006, beginning its nine-year journey to Pluto. When it arrived in July of 2015, New Horizons flew as close as 12,500 kilometres (7,800 miles) to the planet and revealed an incredibly interesting surface. Upon closer inspection of the data the New Horizons team found potential evidence of a subsurface ocean, not just water-ice frozen under the face of the dwarf planet. This could have amazing repercussions in understanding how water exists in the Solar System.

After the New Horizons flyby, planetary scientists have become more interested in Pluto and are desperate to learn as much about it as possible. This has laid down another challenge at NASA's feet which could soon be picked up by the aerospace engineering company Global Aerospace Corporation (GAC), who are interested in creating the 'Pluto Hopper'.

The idea behind this hopper is to drop a lander onto the surface of Pluto using an inflatable balloon to slow down the craft. One issue with this, however, is that Pluto has an incredibly thin atmosphere. It also has a low surface gravity – only six per cent of Earth's – and the spacecraft would have to slow down a lot as it arrives at high speeds. Although these are hard obstacles to overcome when trying to place a lander on the surface of the tiny dwarf planet, they are doable, and scientists and engineers are continuing to work out how to get back to Pluto one day.



The 'Pluto Hopper' is still in the designing phase of its mission

New Horizons and Pluto: a brief encounter

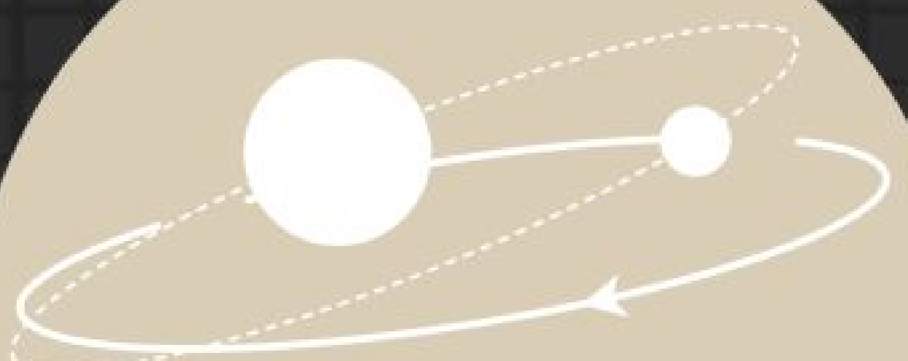
- **Date:** 19 January 2006
  Activity: New Horizons was launched on top of an Atlas V rocket from Cape Canaveral Air Force Station, Florida.
- **Date:** 28 February 2007
  Activity: Had a 'gravity assist' from Jupiter to gather more speed, which reduced its journey time by three years.
- **Date:** 28 June 2007
  Activity: New Horizons went into hibernation for the long journey.
- **Date:** 6 December 2014
  Activity: Engineers woke New Horizons up ahead of its flyby to test equipment.
- **Date:** 15 May 2015
  Activity: New Horizons had officially imaged Pluto in a better resolution than Hubble.
- **Date:** 14 July 2015
  Activity: The day of the flyby had arrived; a historic moment that returned unbelievable data about the dwarf planet.

Pluto's facts and stats

153

One day on Pluto takes 153 hours. It has a retrograde rotation, meaning it spins from east to west.

NASA's New Horizons was the fastest man-made object launched from Earth at 16.26 kilometres (10.10 miles) per second.



Charon, Pluto's largest moon, also takes 153 hours to complete one orbit around Pluto, meaning this moon never rises or sets.

It takes 5.5 hours for sunlight to reach Pluto, as light has to travel 40-times as far than it does to Earth.

1/900

The Sun would be 1/900 the brightness on Pluto than it is on Earth, equal to 300-times the brightness of a full Moon.

Pluto's mountains can reach as high as two to three kilometres (6,500 to 9,800 feet) and are essentially composed of water ice.

There is no evidence to suggest Pluto has a magnetosphere, but its small size and slow rotation suggests it is unlikely.

© NASA; Tobias Roetsch; Adrian Mann;

ASK Space

Our experts answer your questions

EXOPLANETS

Can planets form around dead stars?

The majority of stars will end their lives as white dwarfs, and it is expected that a large fraction of their planetary systems will survive this stellar evolution. There are theories that planets could form from recycled planetary material around white dwarfs, but none have been discovered so far.

However, for evidence of planets that have formed around a dead star, one only has to look at the first exoplanetary system discovered, around the neutron star PSR B1257+12. The planets in this system orbit very close in – the farther planet orbiting PSR B1257+12 orbits at 0.46 astronomical units, or AU; the Earth orbits at one AU – and must have formed after the neutron star, as any previous planetary system would not have survived the birth of the neutron star.

While neutron stars can be formed through multiple channels, one possible scenario is that PSR B1257+12 and its planetary system were formed in a binary merger, where the companion star was ripped apart and formed an accretion disc around PSR B1257+12. This disc not only spun up the neutron star, which rotates around 160 times every second, but also provided the material to form the three planets around PSR B1257+12.

Christopher Manser is a postdoctoral researcher at the University of Warwick, United Kingdom, whose research is focused on remnant planetary bodies around white dwarf stars

The first exoplanets were discovered around PSR B1257+12 in 1990

© NASA/JPL-Caltech

Did you know?

As of June 2019, there are 4,071 confirmed planets in 3,043 different systems. Over 650 systems have been confirmed to host multiple

HUNT FOR LIFE

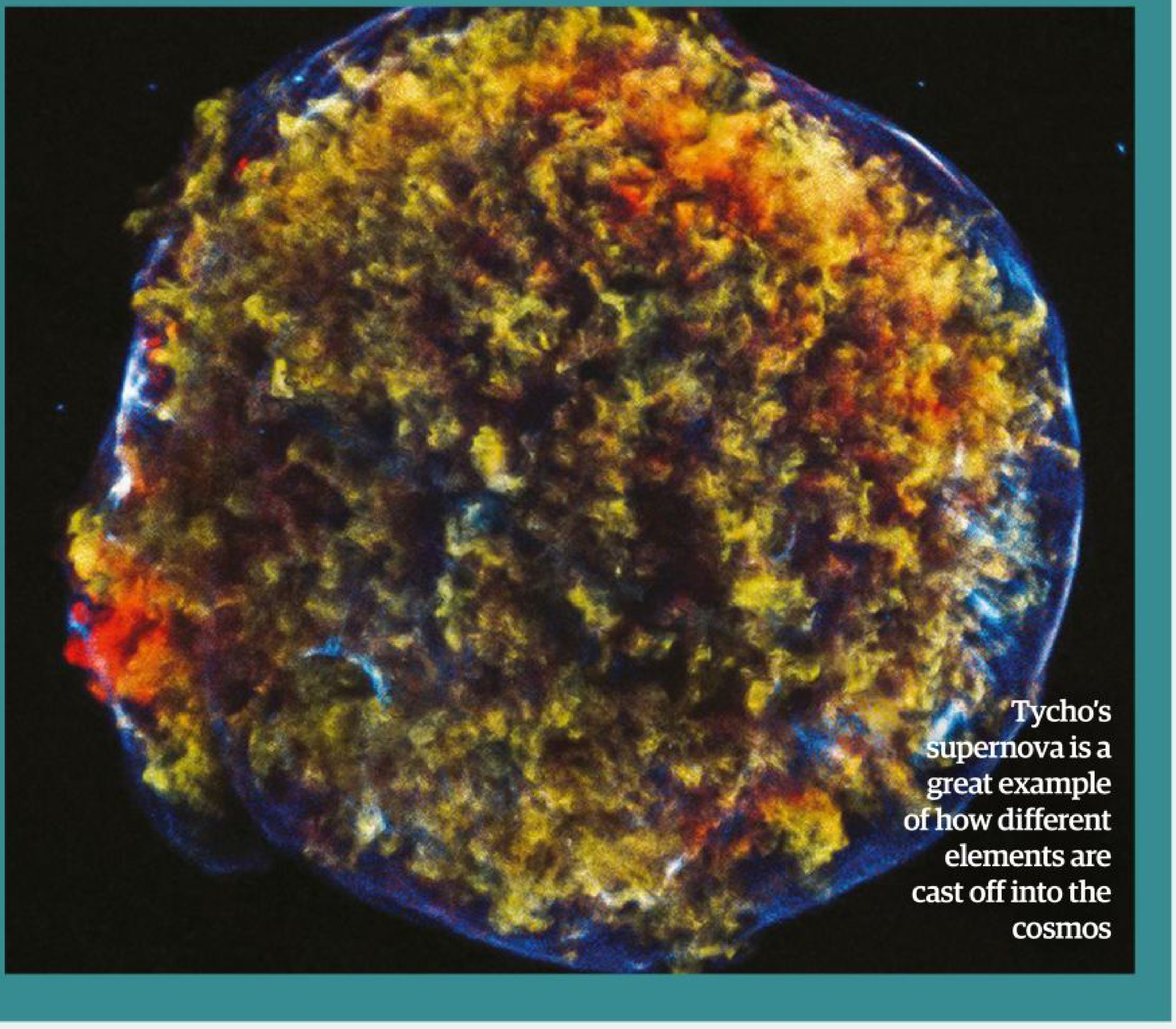
Where do humans truly originate from?

Stars are giant balls of hydrogen gas. In the very centre of a star it's hot enough – millions of degrees hot – that a nuclear fusion reaction is going on. Little tiny atoms of hydrogen – hydrogen is the smallest, simplest atom – ram together in a nuclear fusion reaction, and they make bigger and bigger atoms. The star gets energy out of that, and that's what makes the star shine. The incredible thing is that this is where every atom in the universe comes from, besides the original hydrogen and helium.

Eventually all the hydrogen inside the core is depleted, and then the star dies. Stars like the Sun unravel gently back into space, and all of those wonderful new atoms and elements that it created are being distributed back into space.

The death isn't quite so gentle. In fact, it explodes violently in a supernova explosion. The amazing thing about supernovae, these violent star deaths, is that every atom larger than iron has to be created in this more violent explosion. Iron is the element that makes our blood red; iron combined with oxygen gives you red blood. You better believe – it's actually true – that whenever I bleed, I think about how the iron that makes my blood red was created the instant the star died. Your body literally had to be forged inside a star that died.

Michelle Thaller is assistant director for science communication at NASA's Goddard Space Flight Center in Greenbelt, Maryland, United States



Tycho's supernova is a great example of how different elements are cast off into the cosmos

ASTRONOMY

Why are the conditions in Antarctica ideal for looking at the Cosmic Microwave Background (CMB)?

The CMB is made up of photons from the primeval oven that the universe forged the first elements in. These are the lightest elements, and when they were formed the leftover binding energy of formation was released as a form of heat. That heat propagated throughout the universe for 13.8 billion years until it arrived at our telescopes.

My community has built three satellites, so far, that have been to space to study the CMB, and that's done at great expense and great risk. It's almost 100-times more expensive if we wanted to put BICEP2 in space than the way we built it at the South Pole.

Microwaves are efficient absorbers of water, and water is very much present in the Earth's atmosphere. The atmosphere above the South Pole is very space-like – it's very desert-like. There are very few water molecules in the atmosphere. We don't want these photons that are so precious to us, and so few, travelling across the universe, and all of a sudden they smash into a water molecule in our atmosphere. That's no good. All of our microwave telescopes need to be built at high elevation, in very cold climates or both.

Brian Keating is professor of physics and astronomy at the University of California, San Diego

The South Pole Telescope has the ideal conditions for low-interference astronomy

© NASA; Brucelieberman; Christopher Michel

ASK Space

Our experts answer your questions

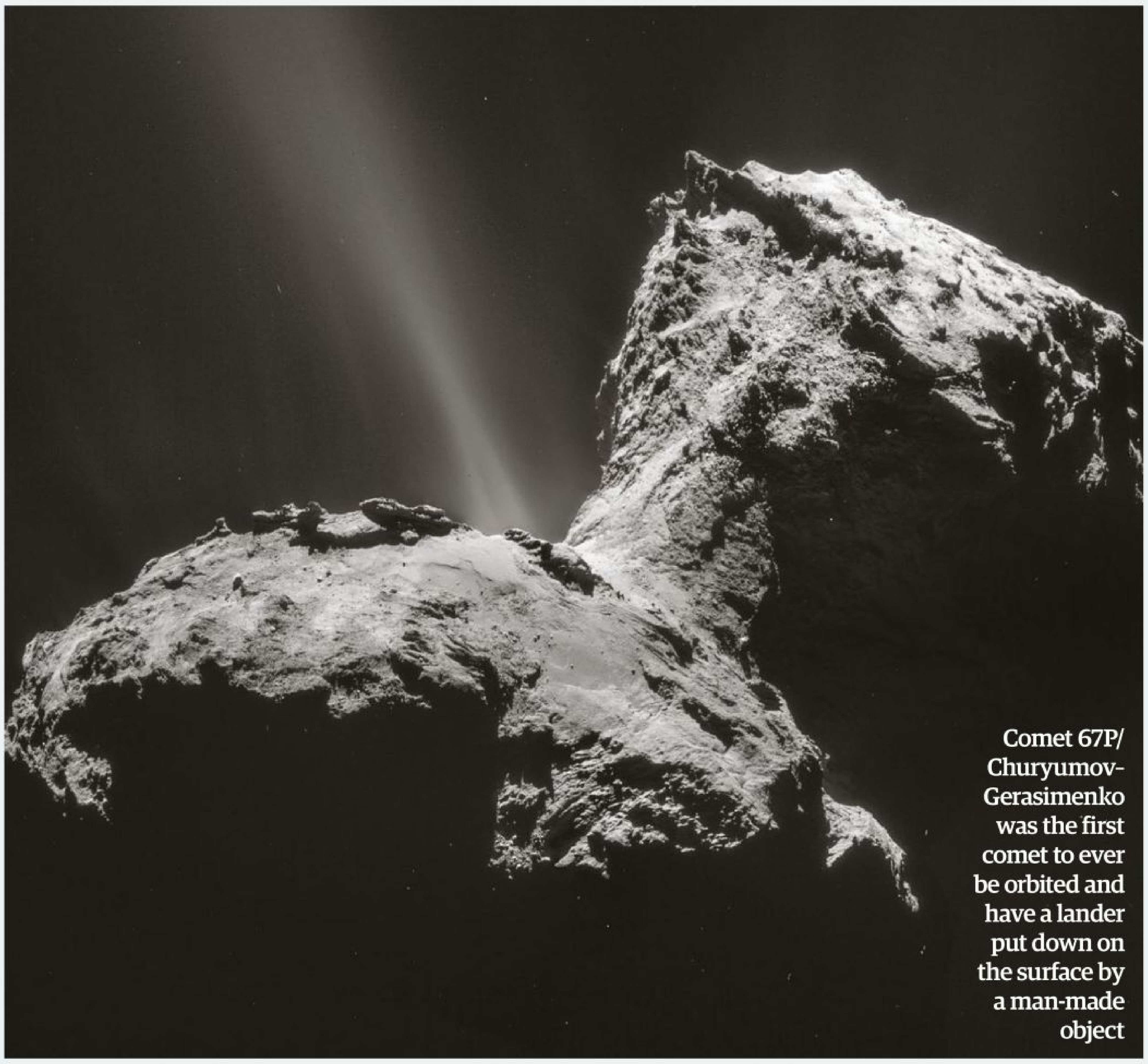
COMETS

What's so fascinating about Rosetta's comet?

It is a fantastically diverse object. It had this very significant bilobed nature not uncommon in comets, but it really was striking with this duck shape. With regards to the surface features and the material we found, it kind of has all the bits of all the comets we've ever observed, and they were all in one comet that we were able to study.

The reason we study them? Because we look at them as treasure chests of what the Solar System was like at its beginning. In fact, some of the stuff we were looking at with Rosetta, for instance the oxygen molecules we discovered on the comet, that was a surprise to us. Because it's there, it constrains how we believe the comet actually formed, so it actually says something about the protostellar cloud. It could be that there is material in that comet that predates the formation of the Sun. So just from studying this funny, duck-shaped object, to me it's mind-blowing that you can make that connection to the entire Solar System's formation. That's why.

Matt Taylor is the project scientist of ESA's Rosetta mission



Comet 67P/Churyumov-Gerasimenko was the first comet to ever be orbited and have a lander put down on the surface by a man-made object

SPACE EXPLORATION

How will Hubble and the James Webb Space Telescope differ?

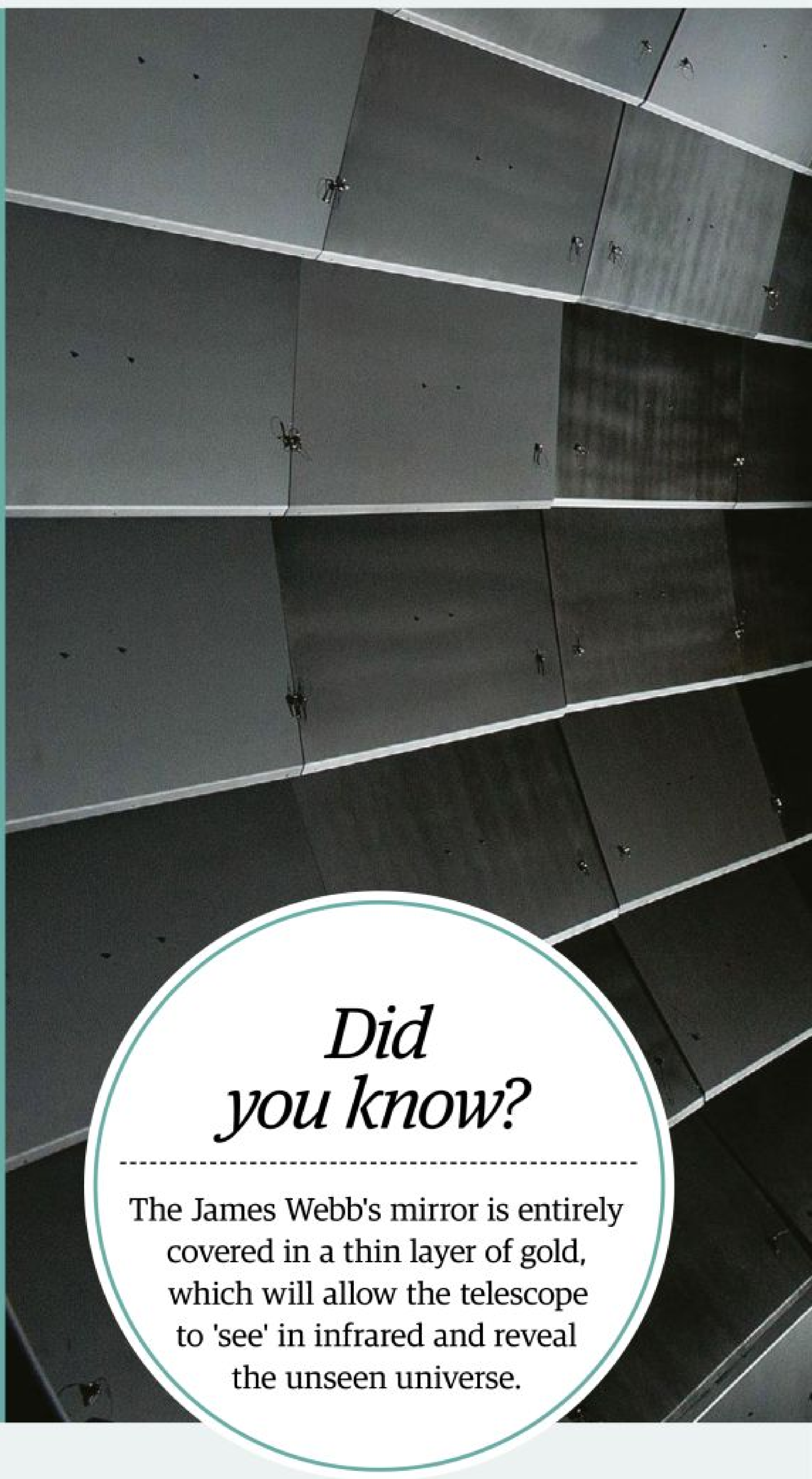
Webb is different from Hubble in a few key ways, and the first is the size. So Webb is big, really big. Webb will be by far the biggest telescope we've ever sent to space. Hubble's about the size of a school bus. From top to bottom, Webb stands over three stories tall and is as wide as a tennis court.

The second big difference between Webb and Hubble is the place in space that Webb will be. Hubble orbits the Earth about 560 kilometres (348 miles) up, which is relatively close. We're going to put Webb out 1.6 million kilometres (994,200 miles) from Earth – that's about four-times further away than the Moon. We put Webb in this part of space so it can get really cold.

And that leads to the third key difference between Hubble and Webb, which is the type of light that Webb will see. Hubble is primarily a visible light telescope; it sees the universe primarily in optical light that your eyes can see. Webb will see the universe in a whole new light, an infrared light. Infrared light is just a little bit more red than what your eyes can see, and Hubble has a little tiny bit of capability in the near-infrared.

Amber Straughn is an astrophysicist at NASA's Goddard Space Flight Center in Greenbelt, Maryland, United States, who is planning for when the James Webb Space Telescope is operational

> "From top to bottom, Webb stands over three stories tall and is as wide as a tennis court"



Did you know?

The James Webb's mirror is entirely covered in a thin layer of gold, which will allow the telescope to 'see' in infrared and reveal the unseen universe.

© NASA; ESA;

SPACE EXPLORATION

Is it possible to fly drones over Mars remotely?

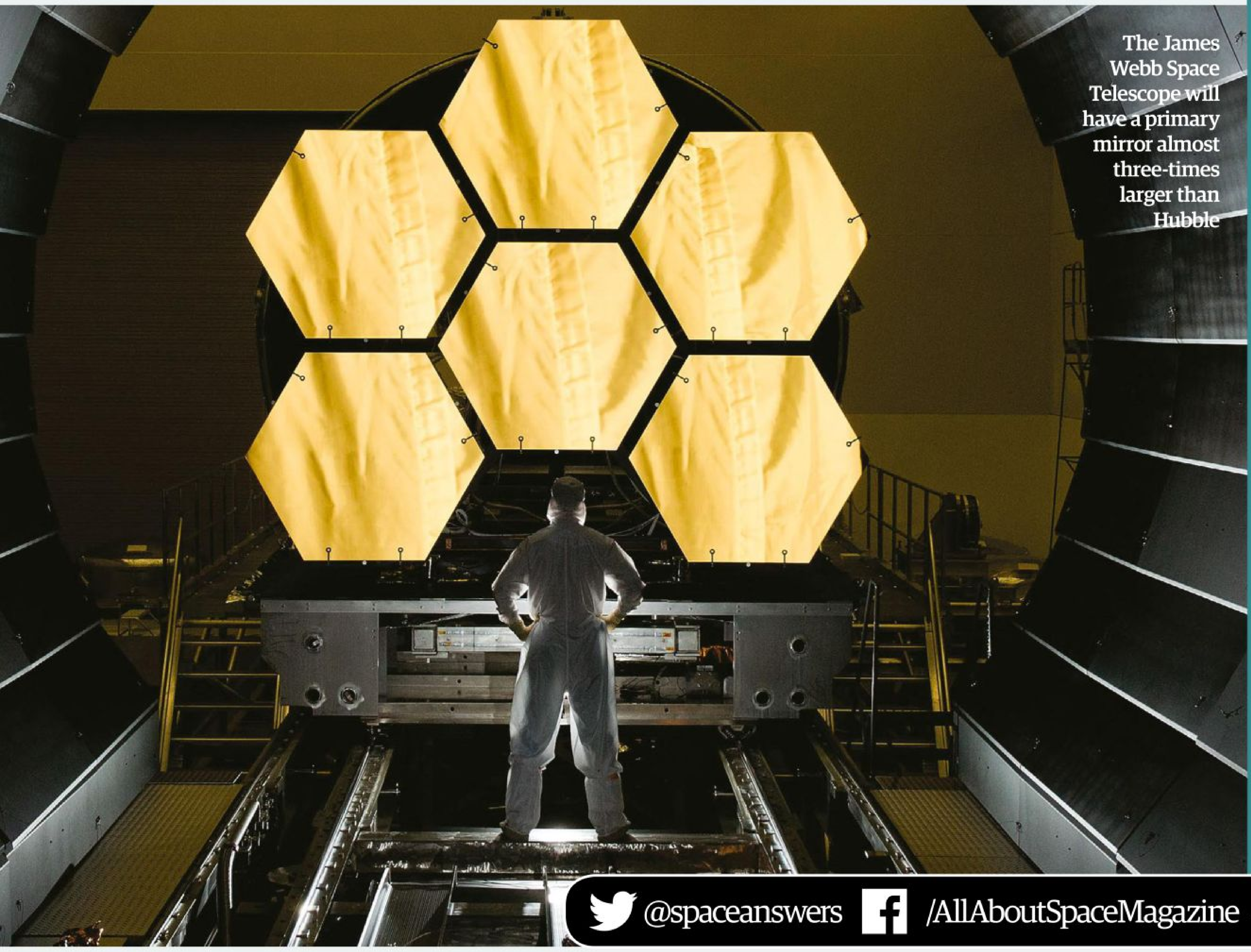
It would not really be possible to fly a Mars drone from Earth – at least not the way we normally think. On Earth we look either at the drone or at video it sends back and directly control it, like we're driving a car. But we don't have the ability to constantly communicate with things at Mars – the Deep Space Network, the set of antennae we use to communicate, is shared for all our spacecraft, and no one can use it all the time.

But even if that weren't the case, Mars is pretty far away. One-way radio signals take four to 23 minutes to arrive. By the time the drone sees something it would be at least eight minutes, and could be up to 46 minutes before you respond to it! However, if you had a 'smart' drone, like the Mars rovers, you could send commands a few times a day to have the drone do large-scale activities that were preprogrammed.

The drone could carry out tasks like "fly to this place, take pictures and come back" on their own, while self-monitoring for problems. This is risky, because if something goes wrong you can't respond immediately, but it would allow you to command from Earth.

Ashley Stroupe is a staff engineer at NASA's Jet Propulsion Laboratory in Pasadena, California, United States

Drones would allow for the exploration of tough terrain on Mars that is hard to access with a rover



The James Webb Space Telescope will have a primary mirror almost three-times larger than Hubble

ASTROPHYSICS

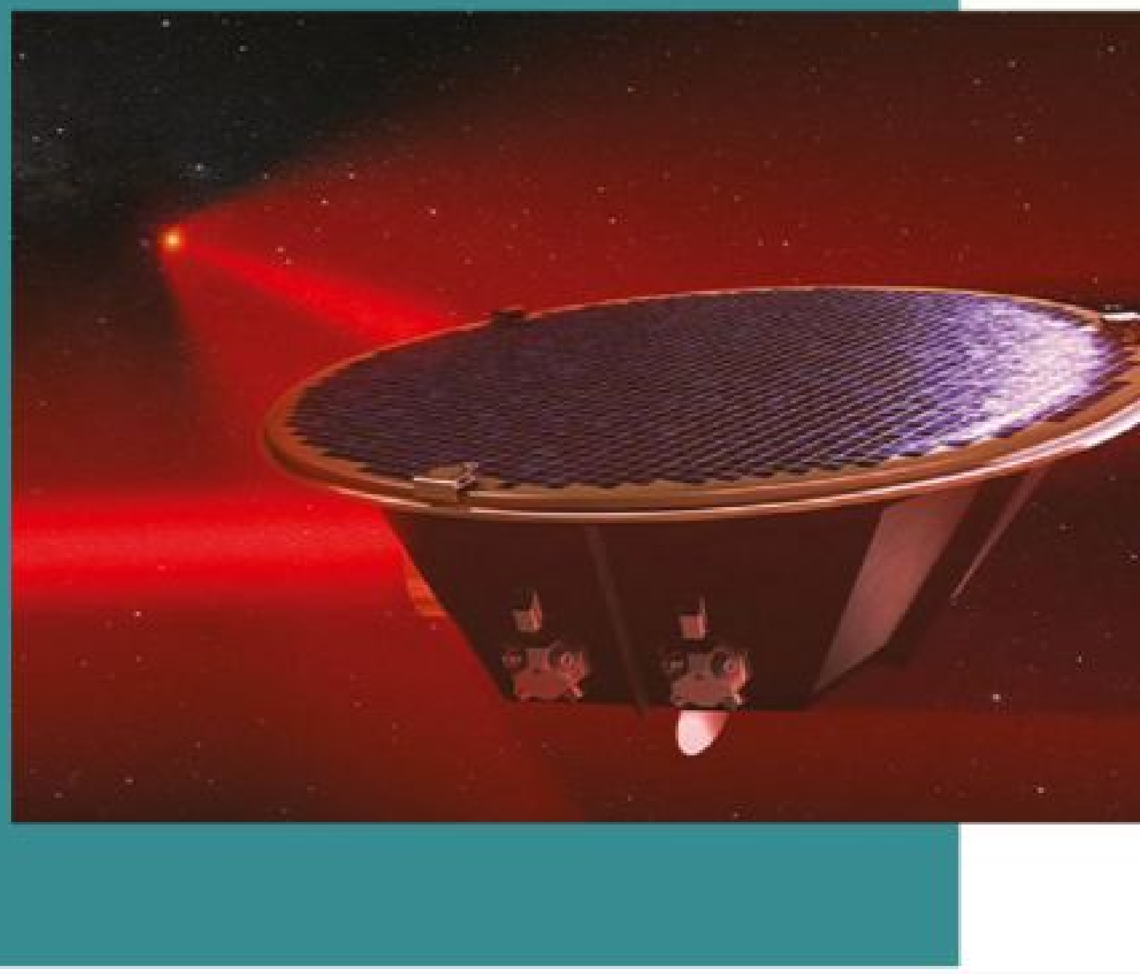
Why is it better to hunt for gravitational waves from space?

Ground-based gravitational wave observatories, for example LIGO and Virgo, have been immensely successful in observing gravitational waves (GW) produced when two stellar origin black holes, or two neutron stars, collide. The observations made over the last few years have introduced us to a completely new way to do astronomy.

Unfortunately low-frequency GW cannot be observed by ground-based detectors for two main reasons: firstly, the Earth is a very noisy environment, with everything from seismic activity to trucks driving past competing to destroy the sensitivity of instruments.

Secondly, the detectors on Earth are just too small! Ideally a GW interferometric observatory will have an arm length equal to one quarter of the gravitational wave wavelength – for a GW frequency of tens of millihertz, this corresponds to arm length of millions of kilometres! Together, it is clear that a space-borne GW detector offers many advantages and is required to observe low-frequency gravitational waves.

Paul McNamara is the study scientist for ESA's LISA mission



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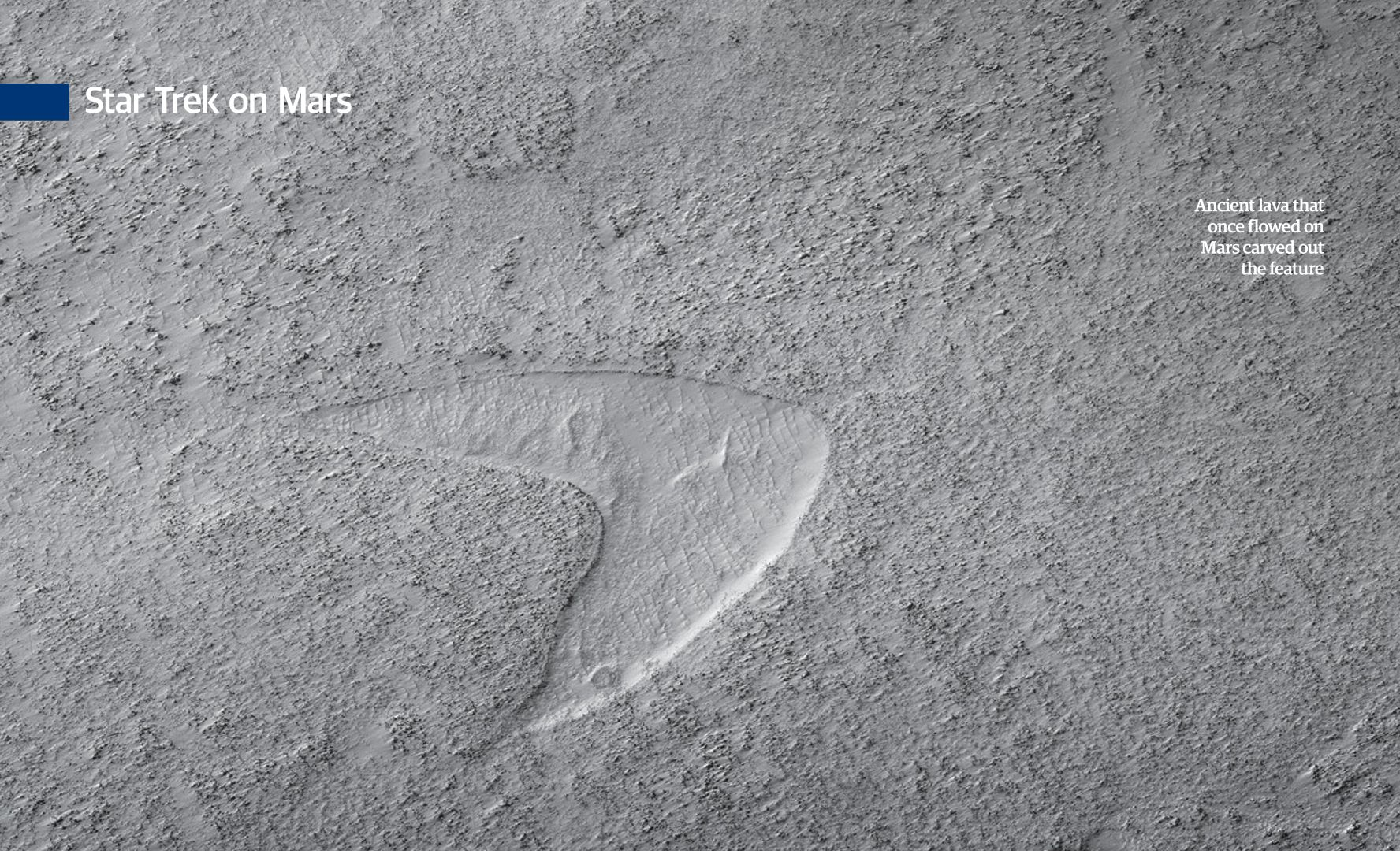

Ancient lava that once flowed on Mars carved out the feature

NASA SPACECRAFT SPOTS *STAR TREK* LOGO ON MARS

Science-fiction fans will recognise the logo shaped by dunes, lava and wind

Reported by Elizabeth Howell

IN COOPERATION WITH SPACE.com

It looks like Starfleet is embedded on the planet next door: a dune in the shape of the famous logo from *Star Trek* appears prominently in a new picture from the Mars Reconnaissance Orbiter (MRO). Even Captain Kirk himself, William Shatner, weighed in.

Don't expect to find Spock, Jean-Luc Picard or Michael Burnham squatting nearby, however. Just like the famous 'face on Mars', this Starfleet logo was produced by random chance as wind, lava and other forces sculpted the Martian landscape.

"Enterprising viewers will make the discovery that these features look conspicuously like a famous logo," the University of Arizona, which manages the MRO HiRISE (High Resolution Imaging Science Experiment) camera, said in a statement. "You'd be right, but it's only a coincidence."

The dune feature is located in Hellas Planitia, a large plain within the Hellas impact basin in the southern hemisphere of the Red Planet. An interaction of dunes, lava and wind formed the chevron shape visible in the picture, according to the statement. The MRO has photographed many other chevrons on Mars, so we're guessing this is not the first time it spotted one shaped like a *Star Trek* logo.

Scientists working with the HiRISE instrument have spent years studying the features they see in Mars images, and they think they have a good sense of how this particular shape came to be. The story starts with crescent-shaped sand dunes where wind and surface interacted.

Then came lava. Eruptions spilled the molten substance across the area surrounding the dunes, but it wasn't thick enough to cover them entirely. And when the lava cooled, the sand dunes remained, "stuck up like islands", according to the statement.

"However, they were still just dunes, and the wind continued to blow," the statement continued. "Eventually the sand piles that were the dunes migrated away, leaving these 'footprints' in the lava plain. These are also called 'dune casts' and record the presence of dunes that were surrounded by lava."

While the *Star Trek* feature is a coincidence, we can truly say that the MRO has lived long and prospered, as the Trekkie saying goes, at the Red Planet. The orbiter has been sending back high-resolution imagery for 13 years, well past its design lifetime. It serves as a vital communications relay for NASA's Curiosity rover and InSight lander and is expected to support the Mars 2020 rover mission when that craft lands on the Red Planet.

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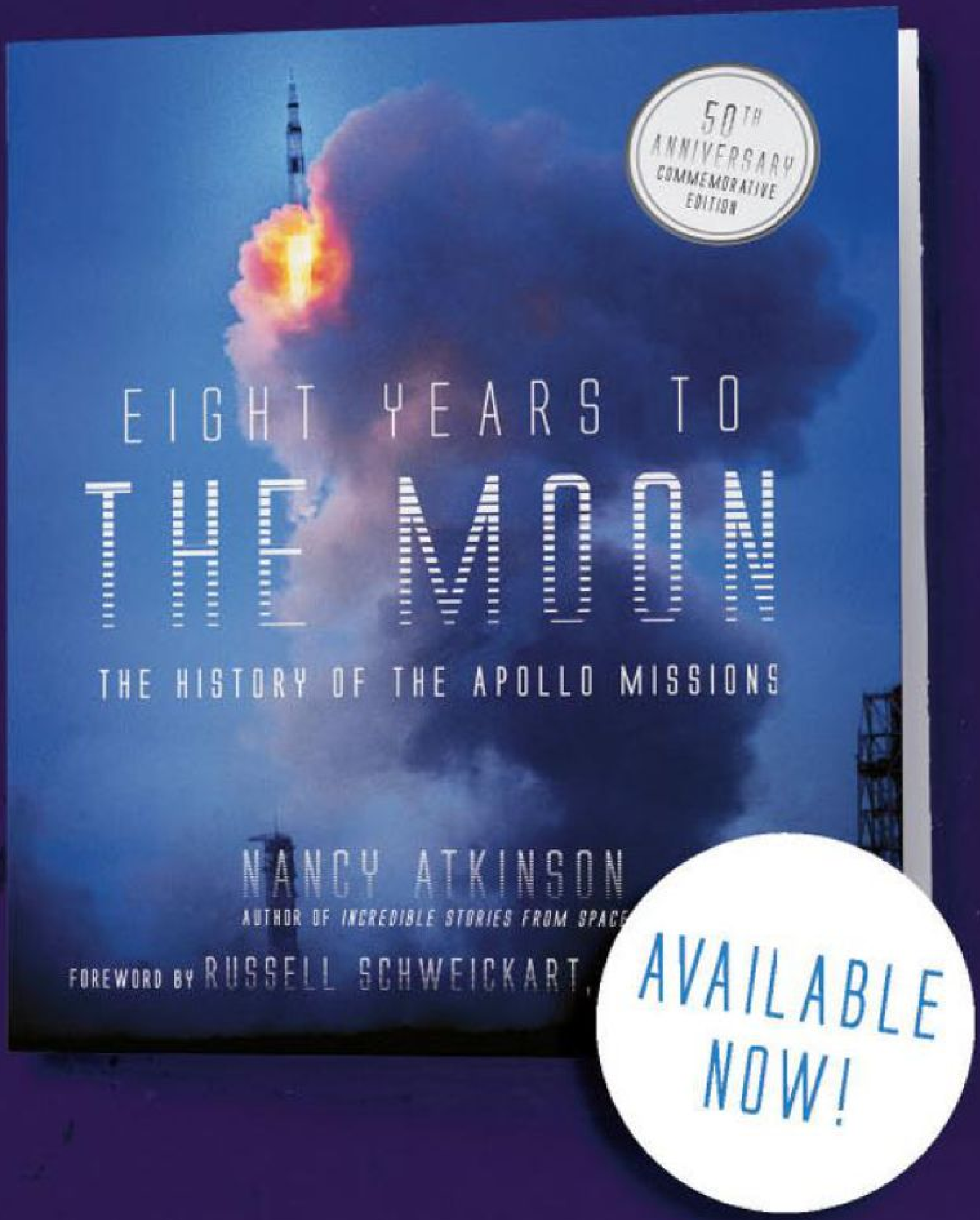
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Charting the stars

The Hertzsprung-Russell diagram

The diagram that's embedded in every astronomer's mind can tell us a lot about the different stars that exist in the cosmos

In the early 1900s the astronomers Ejnar Hertzsprung and Henry Russell placed stars in a plot of a measure of a star's luminosity – the amount of energy a star radiates in a fixed amount of time – against a measure of the star's surface temperature. Such a plot is now called a Hertzsprung-Russell diagram (HRD). The HRD has stimulated astronomers in their understanding of the physical processes responsible for the observed structure and evolution of stars. Additionally, HRDs for stellar clusters have proven extremely useful in determining their ages and distances.

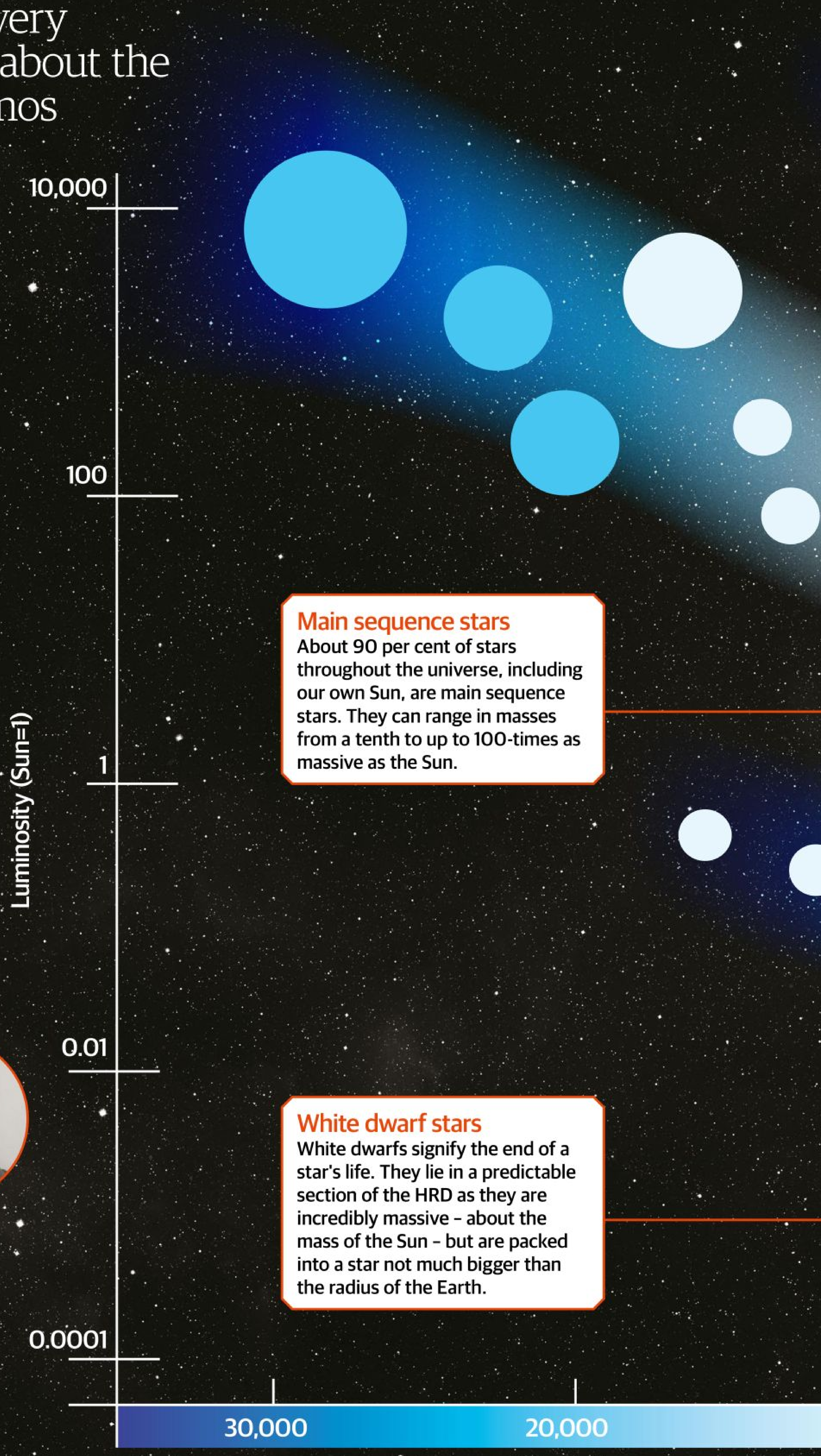
The position of a star in the HRD depends mainly on its mass and its evolutionary state. Most stars lie on the part of the HRD labelled 'main sequence'. Main sequence stars are in the longest-lived stage of their evolution, in which fusion reactions in their central regions are converting hydrogen nuclei into helium nuclei. The star's mass determines its location on the main sequence.

The lowest mass stars, of masses one-tenth that of the Sun, are the coolest and faintest main sequence stars and lie at the bottom of the main sequence. They are red in colour. The most massive stars, of masses 100-times that of the Sun, are the hottest and brightest main sequence stars and are at the top of the main sequence. They are blue in colour.

When the hydrogen fusion reactions in the central regions end, the star's position in the HRD moves away from the main sequence. Stars of mass similar to the Sun become red giant stars, like Arcturus in the constellation of Boötes (the Herdsman). In red giant stars the fusion of hydrogen to helium occurs in a region just outside a central core of mainly helium. When all fusion reactions cease in low-mass stars they end their lives as cooling stellar remnants called white dwarfs. Stars significantly more massive than the Sun become blue supergiants and then red supergiants, like Betelgeuse in the constellation of Orion (the Hunter). These stars will end their lives in supernova explosions, leaving a remnant neutron star or possibly a high-gravity black hole.

BIO
James MacDonald

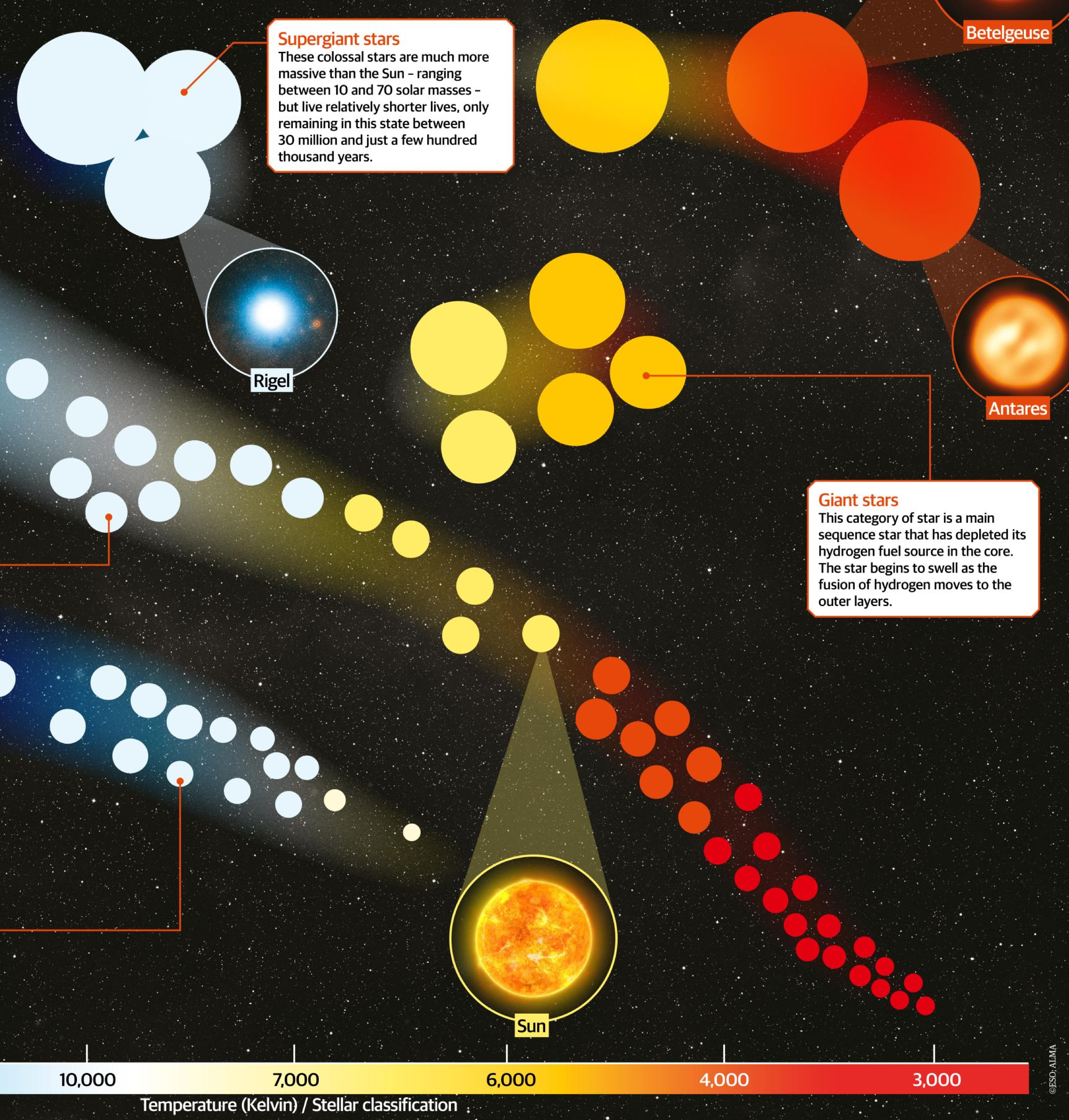
James MacDonald is a professor in the department of physics and astronomy at the University of Delaware. His topics of interest include the evolution of stars from low to high masses throughout the universe.



Main sequence stars
About 90 per cent of stars throughout the universe, including our own Sun, are main sequence stars. They can range in masses from a tenth to up to 100-times as massive as the Sun.

White dwarf stars
White dwarfs signify the end of a star's life. They lie in a predictable section of the HRD as they are incredibly massive – about the mass of the Sun – but are packed into a star not much bigger than the radius of the Earth.

> "When the hydrogen fusion reactions end, the star's position in the HRD moves away from the main sequence"



Supergiant stars

These colossal stars are much more massive than the Sun – ranging between 10 and 70 solar masses – but live relatively shorter lives, only remaining in this state between 30 million and just a few hundred thousand years.

Giant stars

This category of star is a main sequence star that has depleted its hydrogen fuel source in the core. The star begins to swell as the fusion of hydrogen moves to the outer layers.

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The Lunar Module landed on the Moon's surface on the 20th July 1969 and still holds the record for being the first and only crewed vehicle to land anywhere other than Earth. Amazingly, a humble biro pen came to the aid of Buzz Aldrin and Neil Armstrong when a circuit breaker was damaged by the team. By jamming a biro in the circuit breakers hole the module managed to complete the Lunar Ascent!

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Airfix modelling kits allow you to re-create these iconic spacecraft in the comfort of your own home.

A50106
One Step for Man...

A50106 One Step for Man...
Scale 1:72

50 years ago, American, Neil Armstrong became the first man to walk on the Moon. The astronaut stepped onto the Moon's surface, in the Sea of Tranquillity, at 02.56 GMT, nearly 20 minutes after first opening the hatch on the Eagle landing craft. Armstrong had earlier reported the lunar module had landed safely at 20.17 GMT the day before, with the words: "Houston; Tranquillity Base here. The Eagle has landed".

This Airfix Gift Set includes everything you need, including plastic parts paint and glue, to recreate the iconic scenes from the day man first stepped on the moon.

A11170 Apollo Saturn V
Scale 1:144

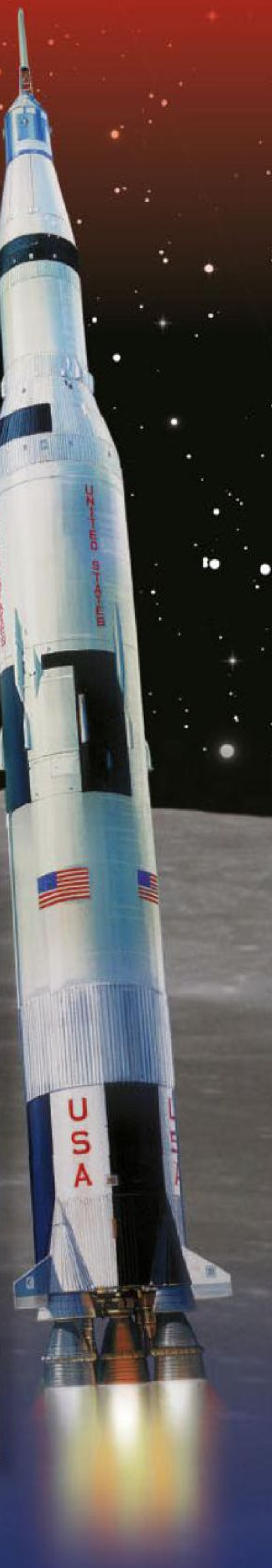
The Saturn V was the largest operational launch vehicle ever produced standing over 363 feet high. It enabled the crew of Apollo 11 and subsequent Apollo crews to leave the pull of the Earth's gravity and reach the moon. Developed at NASA's Marshall Space Flight Center, under the direction of Wernher von Braun, Saturn V was the largest in a family of liquid propellant rockets. The three stage rocket was taller than a 36-story building and was the largest, most powerful rocket ever built.

This Airfix Classic Kit includes 78 pieces for you to assemble and once built stands at 768mm.

A00741V Astronauts
Scale 1:76

This 57 part set consists of US Astronaut action figures and equipment to transport them across the surface of the moon. Includes two moon rovers and various other accessories.

A11170
Apollo Saturn V



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END OF THE MULTIVERSE THEORY?

A posthumous paper by Stephen Hawking cuts cosmology's controversial hypothesis down to size

Reported by Andrew May

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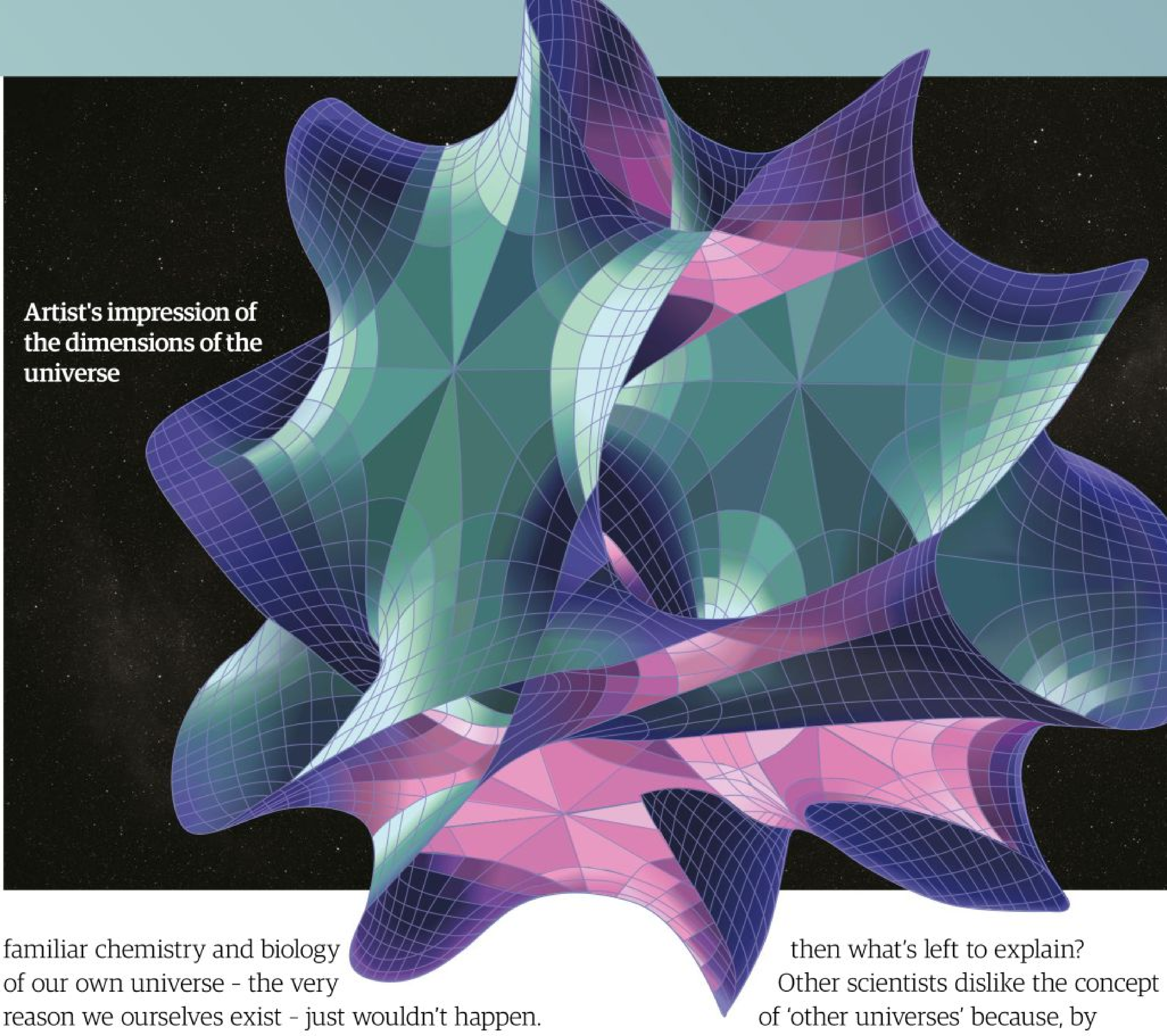
End of the multiverse


Artist's impression of the dimensions of the universe

© Nicholas Froder

The universe, by definition, contains everything we can see. That's not just what we can see with our eyes, but everything within range of our telescopes and other scientific instruments. The universe is what astronomers study, but there's one sub-branch of astronomy – cosmology – which specifically deals with the structure and evolution of the universe on the largest possible scales. The aim of cosmologists is to seek out the simplest theory which adequately explains everything we can see. But the subject took an unexpected turn during the 1980s when that 'simplest theory' began to look distinctly bizarre. It implied the existence of an infinite number of other universes – some very similar to our own, others so different they don't even obey the same laws of physics. According to this theory we live in an unimaginably vast multiverse, of which the whole of the visible universe is merely an infinitesimally small part.

The idea was controversial, to say the least. Some people loved it – the sci-fi community, for example, which had already been talking about 'parallel universes' for decades. In fact, Isaac Asimov's classic novel *The Gods Themselves*, first published in 1972, even speculated that some of the other universes might have different values of the fundamental physical constants – invariant numbers which specify things like the strength of gravity and nuclear forces. And now the real-world multiverse theory was saying exactly the same thing.

Other people who took to the multiverse theory were philosophers, who had always been perplexed as to why those fundamental constants have the precise values they do. That's not just an abstract academic problem, but an acute existential one. If the numbers were even slightly different, the familiar chemistry and biology of our own universe – the very reason we ourselves exist – just wouldn't happen. But if there are infinitely many universes, then all possible combinations of constants are possible – and we simply got the one that works for us.

There were opposing views, too. For a start, the concept of an infinite number of universes is a disquieting one. If there's literally no limit to the universes that can exist, then anything is possible. As well as outlandishly different ones, there'll be countless universes which diverge from our own in the tiniest details – one in which you become president of the United States, for example. Some scientists hate that idea because it effectively destroys their job, which is to explain why the universe is the way it is. If anything can happen – and does happen somewhere in the multiverse – then what's left to explain?

Other scientists dislike the concept of 'other universes' because, by definition, we can never observe them. The only way to test the multiverse theory is to look for its indirect effects – and those effects might have equally good alternative explanations.

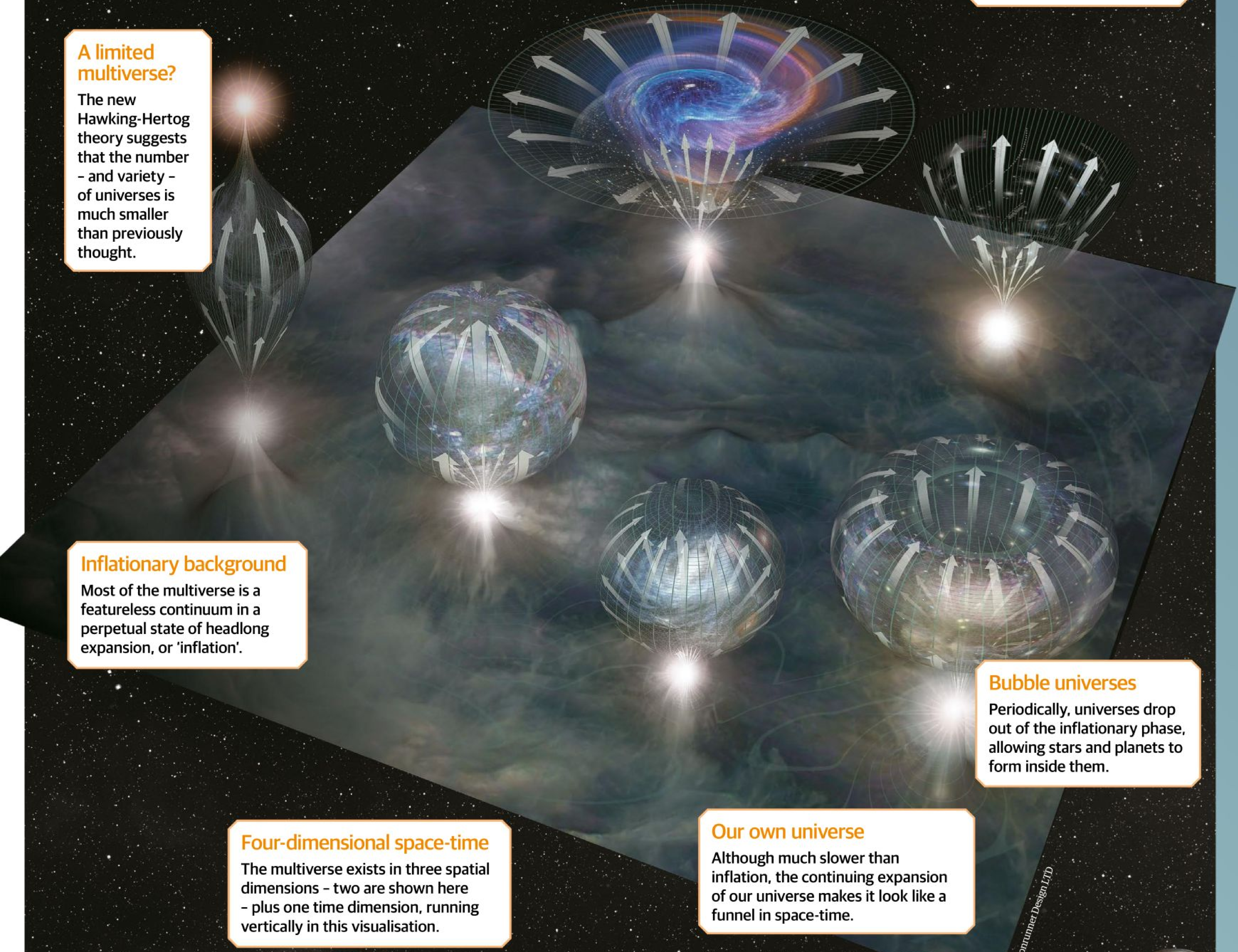
There's now another argument against the multiverse theory. The very line of reasoning that implied that it's unavoidable may have been flawed. This new argument comes from an impeccably high authority – legendary physicist Stephen Hawking. Days before he died in March last year, the *Journal of High Energy Physics* received a paper that he'd co-written with Belgian cosmologist Thomas Hertog. In its own words, the paper proposed "a significant reduction of the multiverse to a much more limited set of possible universes".

Our universe appears 'fine-tuned' to produce planets, stars and galaxies – other universes might be different

© Tobias Roetsch

What is the multiverse?

According to the theory, our universe is just one of many



A young universe

New universes can pop up at any time, so some are smaller and younger than ours.

Closed universes

Some universes are expanding even slower than ours, so they eventually fall back on themselves and self-destruct.

A limited multiverse?

The new Hawking-Hertog theory suggests that the number – and variety – of universes is much smaller than previously thought.

Inflationary background

Most of the multiverse is a featureless continuum in a perpetual state of headlong expansion, or 'inflation'.

Bubble universes

Periodically, universes drop out of the inflationary phase, allowing stars and planets to form inside them.

Four-dimensional space-time

The multiverse exists in three spatial dimensions – two are shown here – plus one time dimension, running vertically in this visualisation.

Our own universe

Although much slower than inflation, the continuing expansion of our universe makes it look like a funnel in space-time.

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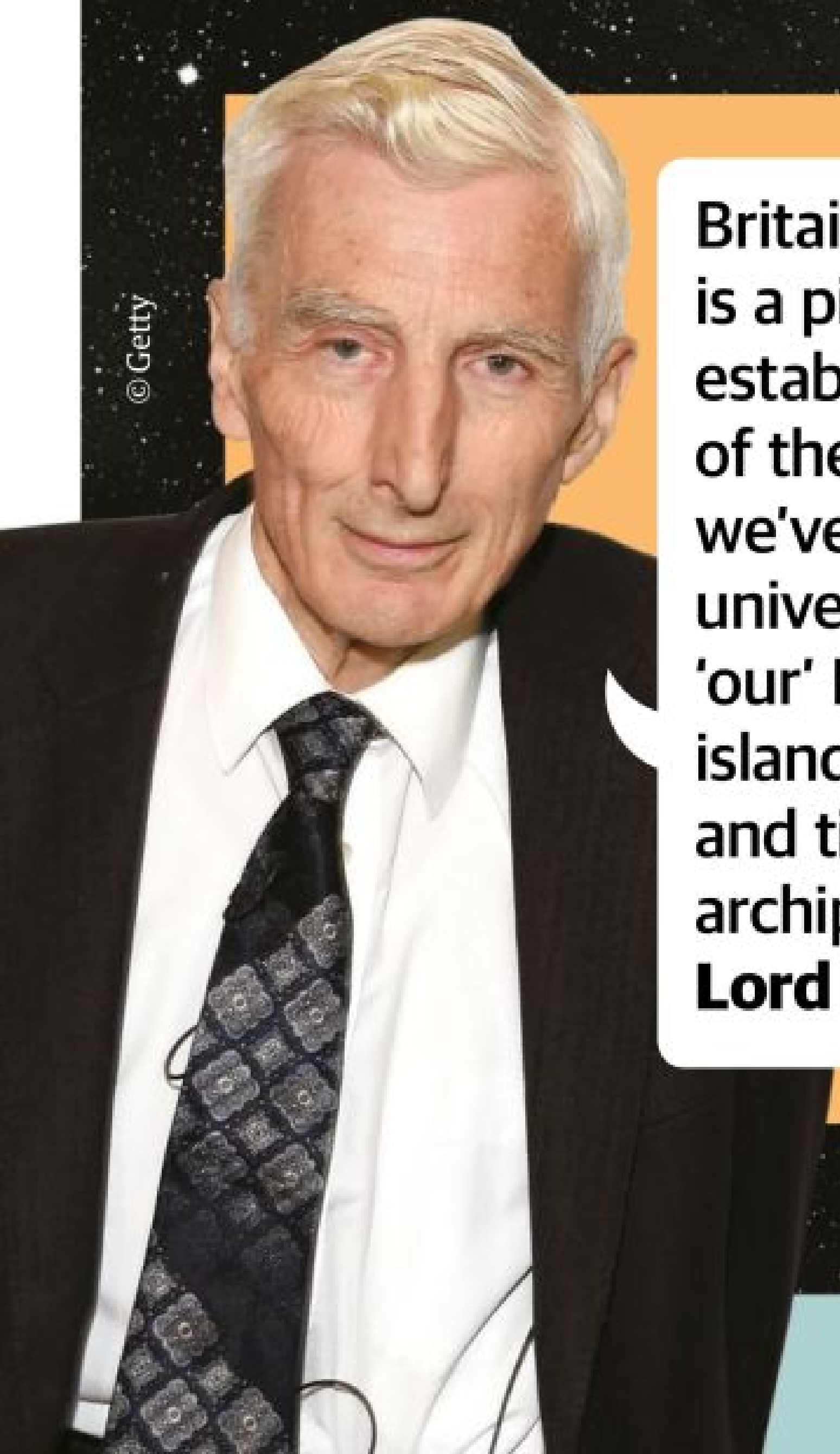
For and against the multiverse

Always a controversial theory, there are high-profile proponents on both sides of the argument

FOR



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Britain's Astronomer Royal is a pillar of the scientific establishment, and an advocate of the multiverse theory. "What we've traditionally called the universe – the aftermath of 'our' Big Bang – may be just one island, just one patch of space and time, in a perhaps infinite archipelago," he wrote last year.

Lord Martin Rees

AGAINST

The principle behind the multiverse, eternal inflation, explains many observations, but so does Penrose's rival theory, called 'conformal cyclic cosmology'. This too involves an infinite number of universes, but they're sequential, with the death of one leading to the birth of the next.

Professor Sir Roger Penrose

The Hawking-Hertog paper still talks about plural 'universes', because there are others lying beyond the visible horizon of our own universe. But those other universes are finite in number and – more importantly – they all obey the same laws of physics. The result is less a multiverse than a scaled-up version of our own familiar universe: "An ensemble of universes which evolve in a way similar to ours," as Hertog put it. In his final paper on cosmology, Hawking may have heralded the end of the multiverse theory. The work was motivated by the nagging feeling that there's something fundamentally 'unscientific' about the concept of a limitlessly diverse cosmos. As Hawking admitted in 2017: "I have never been a fan of the multiverse. If the scale of different universes in the multiverse is large or infinite, the theory can't be tested."

It was a situation that Hawking and Hertog set out to put right. To quote Hertog: "The key challenge facing modern fundamental cosmology is to turn the multiverse into a proper verifiable scientific framework. With our paper, we take a step in this direction."

He goes on to describe the background against which the new research was done: "The prevailing theory of the Big Bang is called eternal inflation. It says that out of the Big Bang not only our own universe arose, but also many other universes – the so-called multiverse. You can picture the multiverse as a mosaic of pocket universes, somewhat like bubbles in boiling water. The laws of physics and chemistry can differ from one pocket universe to another. Some pocket universes contain stars and harbour life, others are nearly empty."

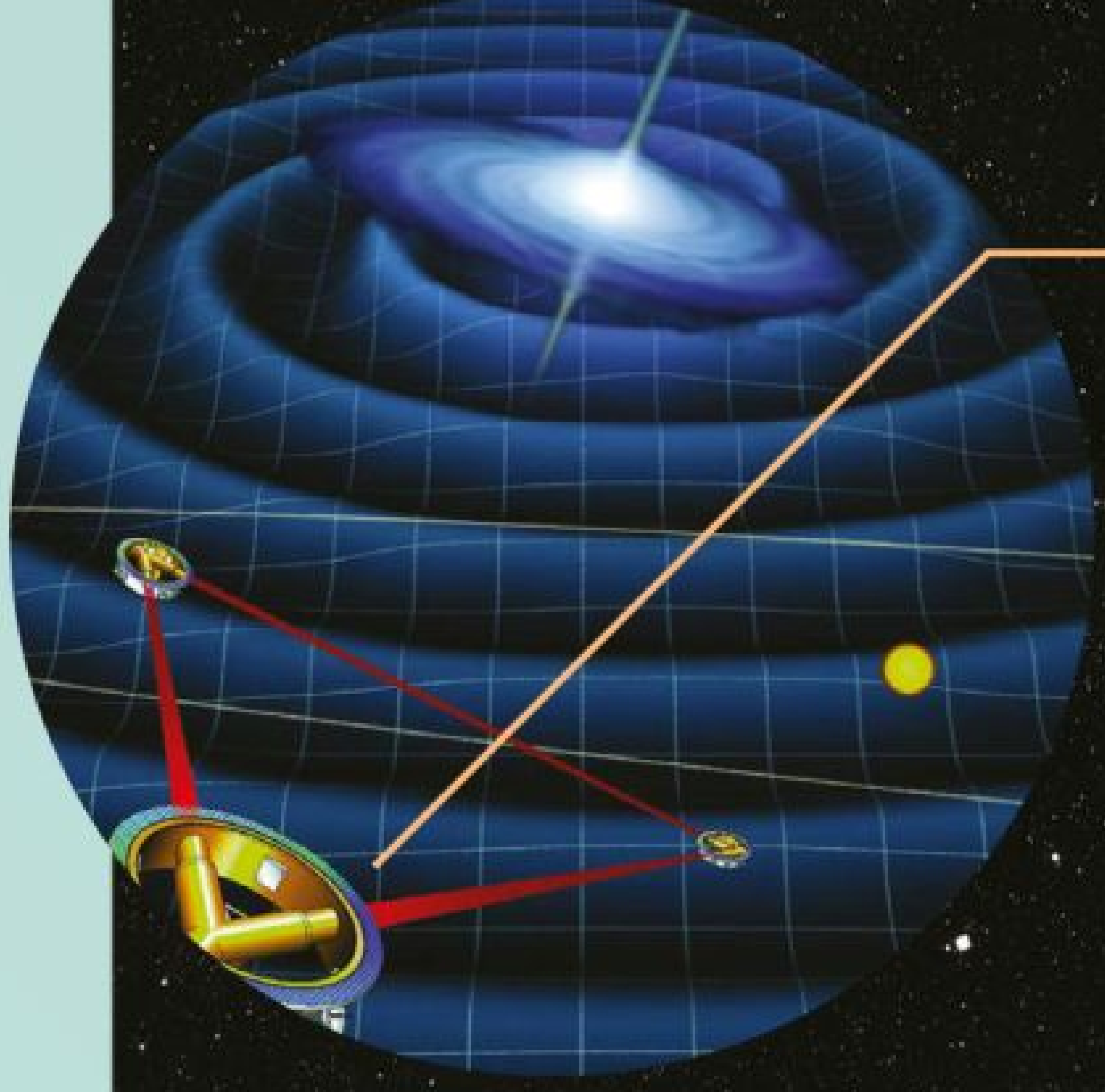
It's this picture – eternal inflation – that cosmologists have considered pretty much inevitable since the 1980s. It comes out of Einstein's theory of gravity, one of the mainstays of modern physics, general relativity. The breakthrough that Hawking and Hertog made was in realising that this wasn't the best methodology to apply to the earliest moments of the Big Bang, because at that time the physical scale of the universe was so tiny. In their view, another branch of modern physics – quantum theory – was indispensable to a full understanding of the problem.

Yet the quantum aspects were something previous work had tended to gloss over. As Hertog explains: "The problem with the usual account of eternal inflation is that it assumes an existing background universe that evolves according to Einstein's theory of general relativity, and treats the quantum effects as small fluctuations around this." To avoid the same error his work with Hawking used string theory, which Hertog describes as "a branch of theoretical physics that attempts to reconcile general relativity with quantum physics".

> "If the scale of different universes in the multiverse is large or infinite, the theory can't be tested" **Stephen Hawking**

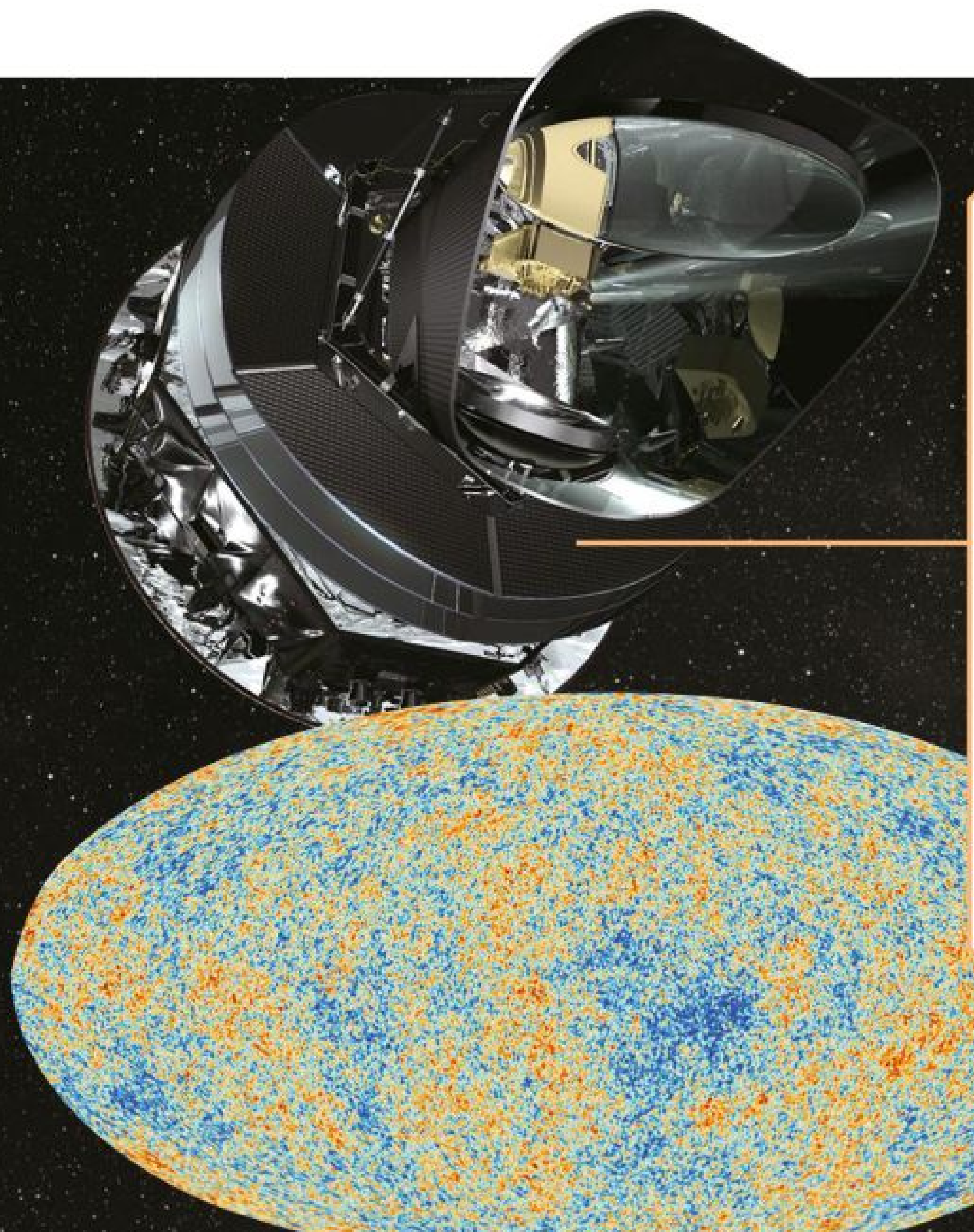
Testing the multiverse theory

How we'll use scientific instruments and results to detect signs of many universes



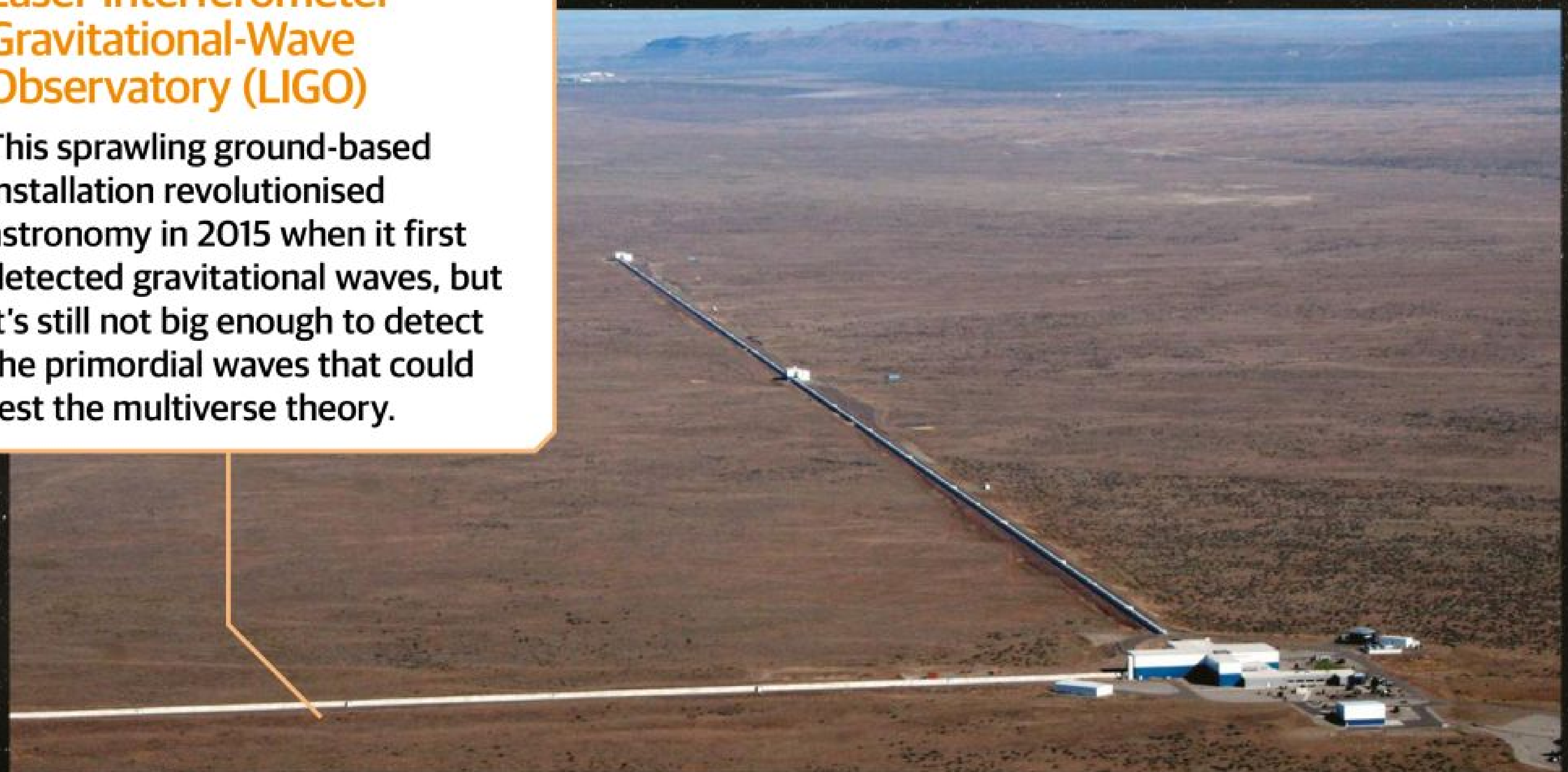
Laser Interferometer Space Antenna (LISA)

An ESA mission planned for the 2030s, this would be a giant gravitational wave detector made up of three spacecraft millions of kilometres apart. It will have a good chance of detecting primordial gravitational waves.



Planck space telescope

ESA's follow-on to WMAP, Planck was operational from 2009 to 2013, remapping the CMB with higher sensitivity and resolution than its predecessor. It confirmed both the inflation-like uniformity and the anomalous cold spot.



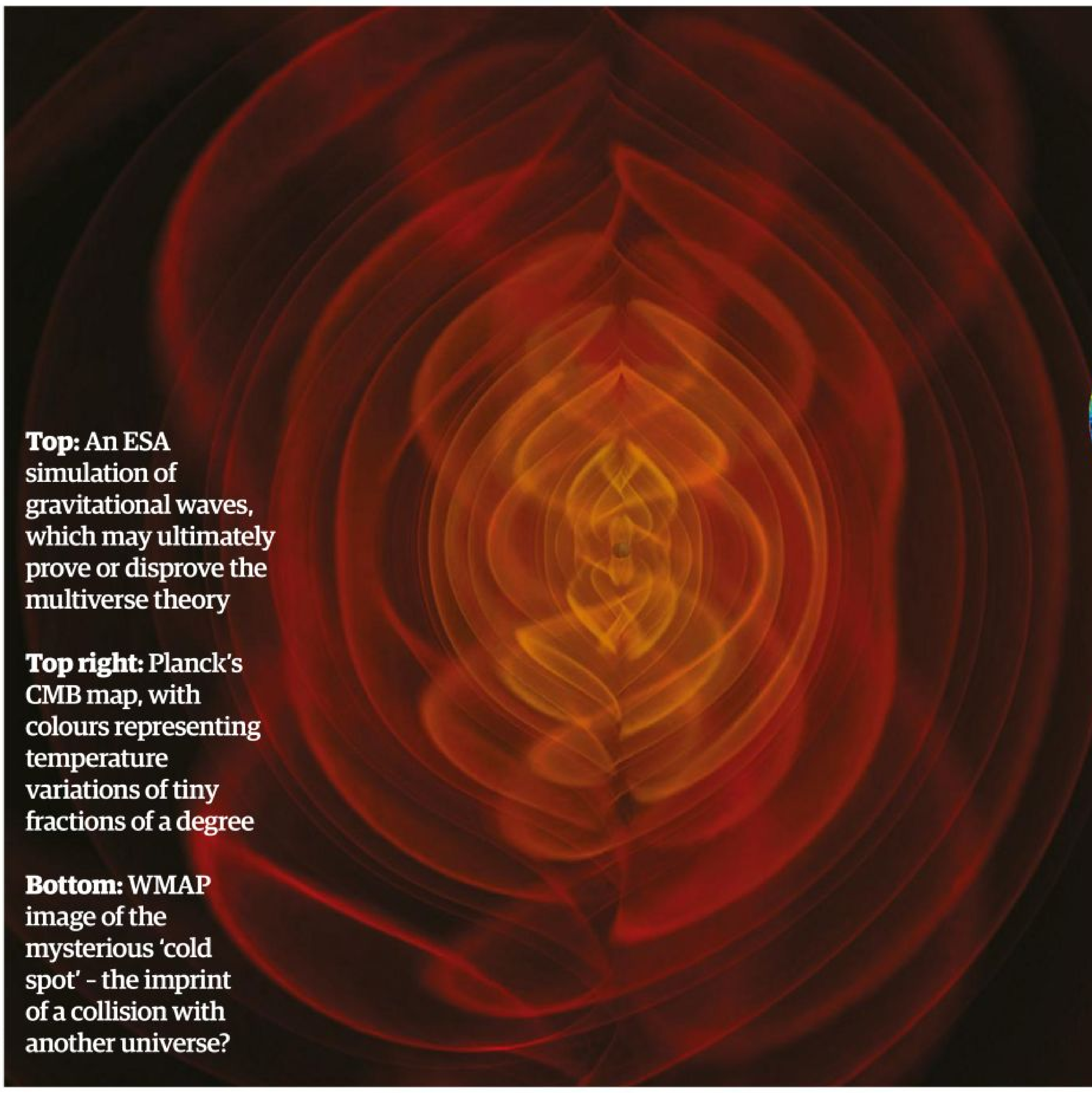
Laser Interferometer Gravitational-Wave Observatory (LIGO)

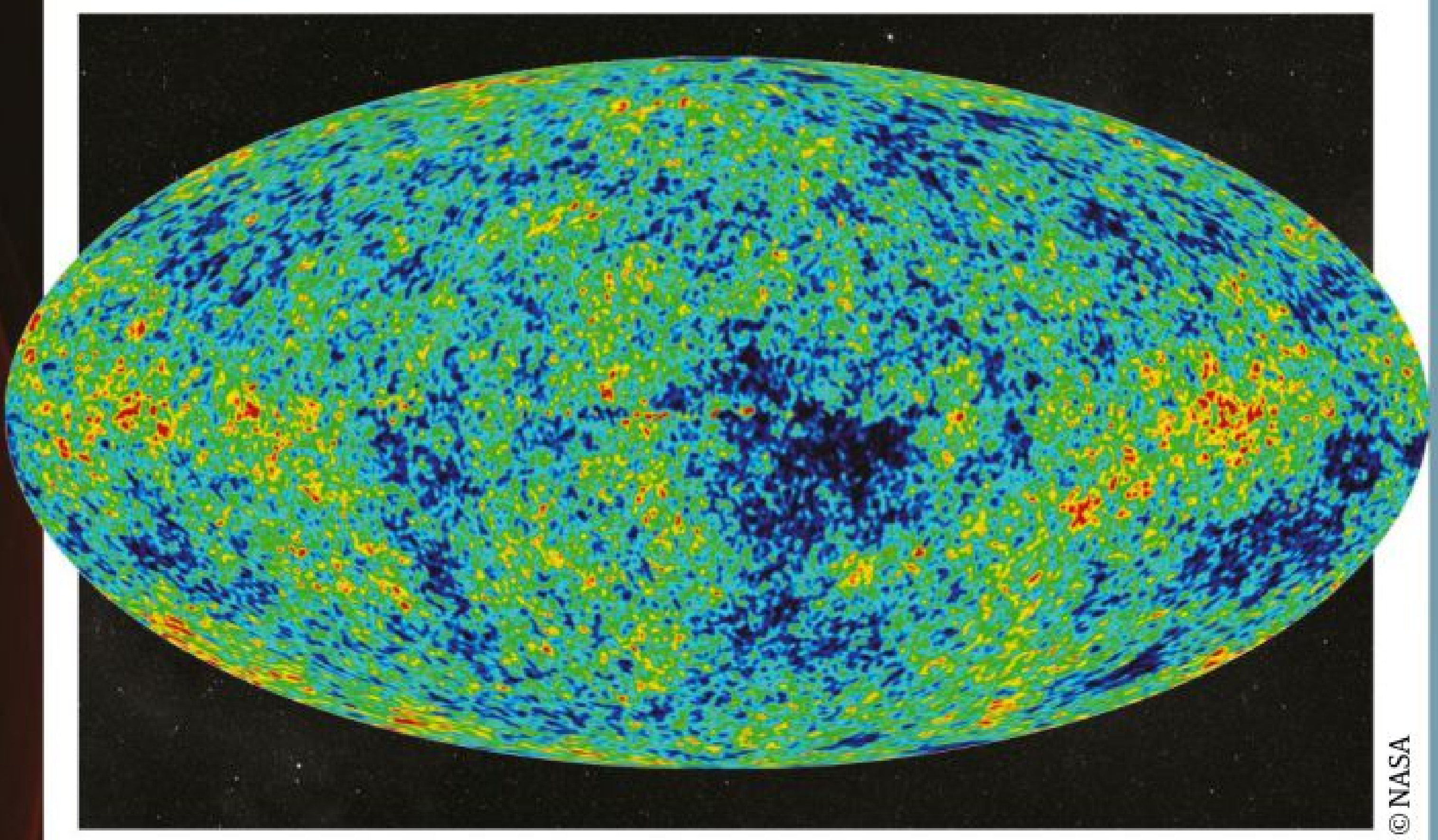
This sprawling ground-based installation revolutionised astronomy in 2015 when it first detected gravitational waves, but it's still not big enough to detect the primordial waves that could test the multiverse theory.

Wilkinson Microwave Anisotropy Probe (WMAP)

Operating between 2001 and 2010, this NASA spacecraft mapped the CMB, confirming the astonishing uniformity which is a hallmark of inflation. It also discovered the 'cold spot' – a possible collision with a neighbouring universe.

© NASA; Alamy





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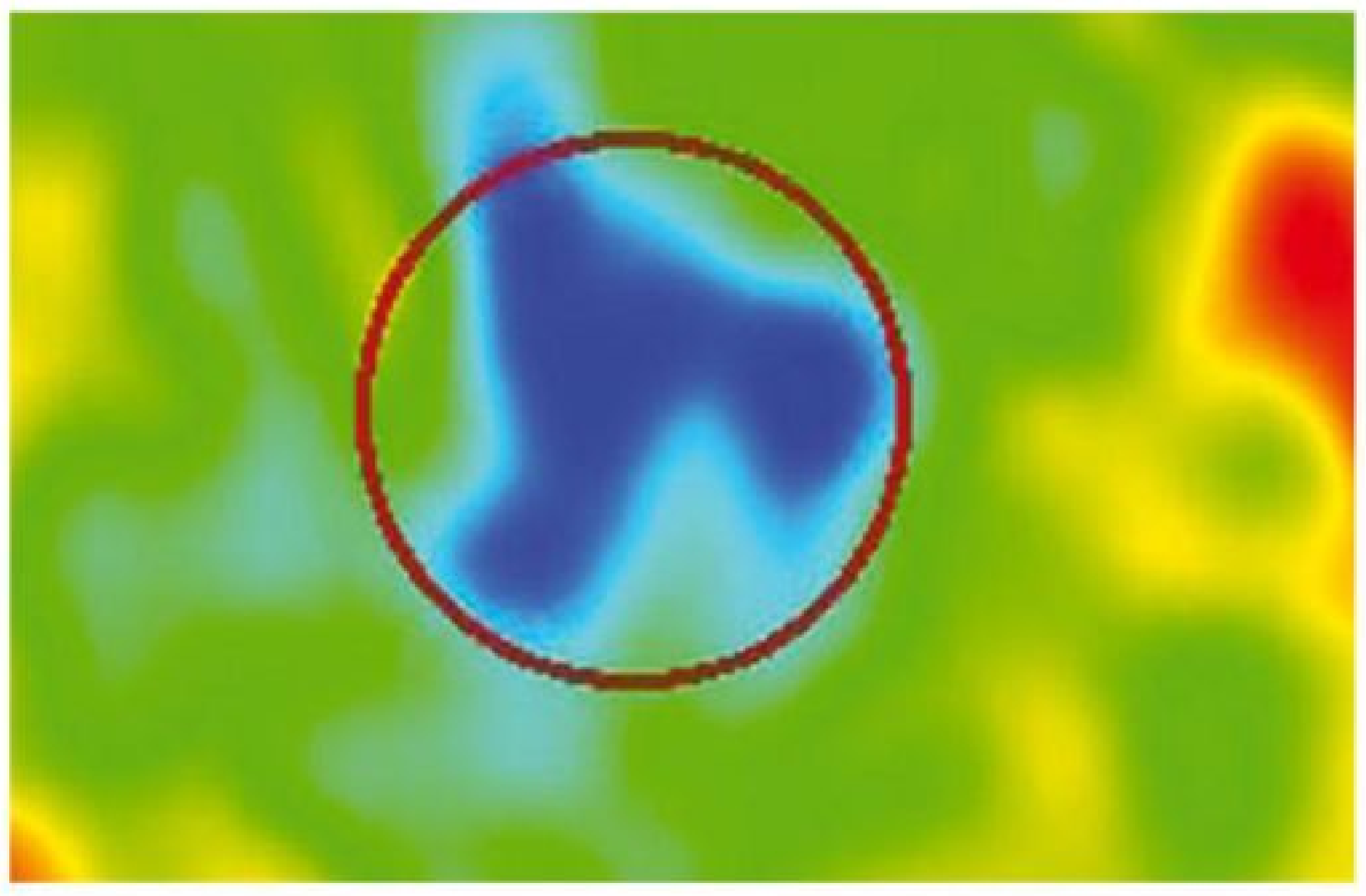

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Top: An ESA simulation of gravitational waves, which may ultimately prove or disprove the multiverse theory

Top right: Planck's CMB map, with colours representing temperature variations of tiny fractions of a degree

Bottom: WMAP image of the mysterious 'cold spot' – the imprint of a collision with another universe?

© NASA

When they tried applying string theory techniques to cosmology they found that, in Hertog's words: "Time evolution is emergent, not built in. In our theory, the universe that evolves in time emerges from a timeless state at the Big Bang. In our paper we put forward a mathematical model for the state of the universe at the beginning. We then use this to predict what kind of universes can come into existence."

The result will be good news for anyone who's uncomfortable with the infinite diversity of the multiverse. There are no weird new laws of physics, no random choices of fundamental constants in different universes. Instead, as Hertog says, "We predict the universe looks roughly the same everywhere, whereas this was radically different in the old theory of eternal inflation."

The new theory has another advantage, too. Hertog claims that cutting the multiverse down to a smaller range of possible universes "makes the theory more predictive and testable". That's obviously a good thing – but it's still a pretty tall order. How do you go about proving or disproving the existence of other universes? Or discriminating between different theories, such as this new one, the traditional multiverse of eternal inflation and various alternatives that have been put forward, like the 'conformal cyclic cosmology' of Oxford physicist Roger Penrose. One place to look for an answer – and the Holy Grail of modern observational cosmology – is the cosmic microwave background (CMB).

This is a sea of electromagnetic radiation, originating soon after the Big Bang, which permeates the whole of space. Observations by spacecraft such as NASA's Wilkinson Microwave Anisotropy Probe (WMAP) and ESA's Planck mission have shown that the CMB is extremely uniform all over the sky. In fact this uniformity provided the original impetus for the concept of inflation – a sudden ballooning of the early universe at an enormously greater rate than the far more sedate expansion we see today.

According to the eternal inflation theory, this super-fast inflation continues indefinitely throughout most of the multiverse, with just small bubbles – our own universe being one of them – switching over to a slower rate of expansion, allowing ordinary matter like stars and planets to appear. But if our horizon is limited to our own bubble universe, how can we hope to observe any of the others?

One possibility is that as our bubble expands, it might collide with another adjacent bubble. It's been theorised that this could leave an imprint on the CMB – a localised region at a slightly different temperature from its surroundings. As it happens, we do see exactly this sort of thing – a 'cold spot' that was discovered by WMAP in 2007, and later confirmed by Planck. The most pedestrian explanation for the cold spot would be a random statistical fluctuation, but work carried out at Durham University in 2017 indicates that this is unlikely.

As Professor Tom Shanks said at the time: "We can't entirely rule out that the spot is caused by an unlikely fluctuation… but if that isn't the answer, then there are more exotic explanations. Perhaps the most exciting of these is that the cold spot was caused by a collision between our universe and another bubble universe. If further, more detailed analysis of CMB data proves this to be the case then the cold spot might be taken as the first evidence for the multiverse – and billions of other universes may exist like our own."

Aside from the CMB, there's another observational possibility in the form of gravitational waves. These have become a familiar astronomical tool in the last few years, with detections of such waves – produced, for example, by merging black holes – by the Laser Interferometer Gravitational-Wave Observatory (LIGO). On a much larger scale, it's likely that gravitational waves would have been generated as the universe dropped out of its inflationary phase.

It's a prospect that Hertog is enthusiastic about: "The most promising observables, when it comes to our local universe, are probably gravitational waves – not from the coalescence of black holes, but gravitational waves that are probably generated at the Big Bang, basically. The creation of space and time goes together with the generation of gravitational waves in our theory, and perhaps the detailed pattern of those gravitational waves will give us a key signature of our model."

There's a catch, though. Any gravitational waves that were produced in the early universe would have a very long wavelength, putting them outside the capability of LIGO and similar Earth-based observatories. But the ESA has plans to put a gravitational wave detector into space, in the form of the Laser Interferometer Space Antenna, or LISA. This would use multiple spacecraft to create a huge observatory in orbit around the Sun – and, as Hertog says, "should be ideally suited to capture those gravitational waves from the Big Bang".

What will those waves tell us? Do we live in an infinite multiverse, a more limited one of the type proposed by Hawking and Hertog or a solitary universe as envisioned by people like Roger Penrose? The answer may come from LISA, but we'll have a tantalising wait before it does, because the mission won't get of the ground for another 15 years. In the meantime it's not quite the end of the multiverse theory yet, but it's certainly on a shakier footing than it was a few years ago.

TABLE SALT FOUND ON EUROPA

For the last 20 years, astronomers had no idea that something quite familiar was present on the face of Jupiter's moon

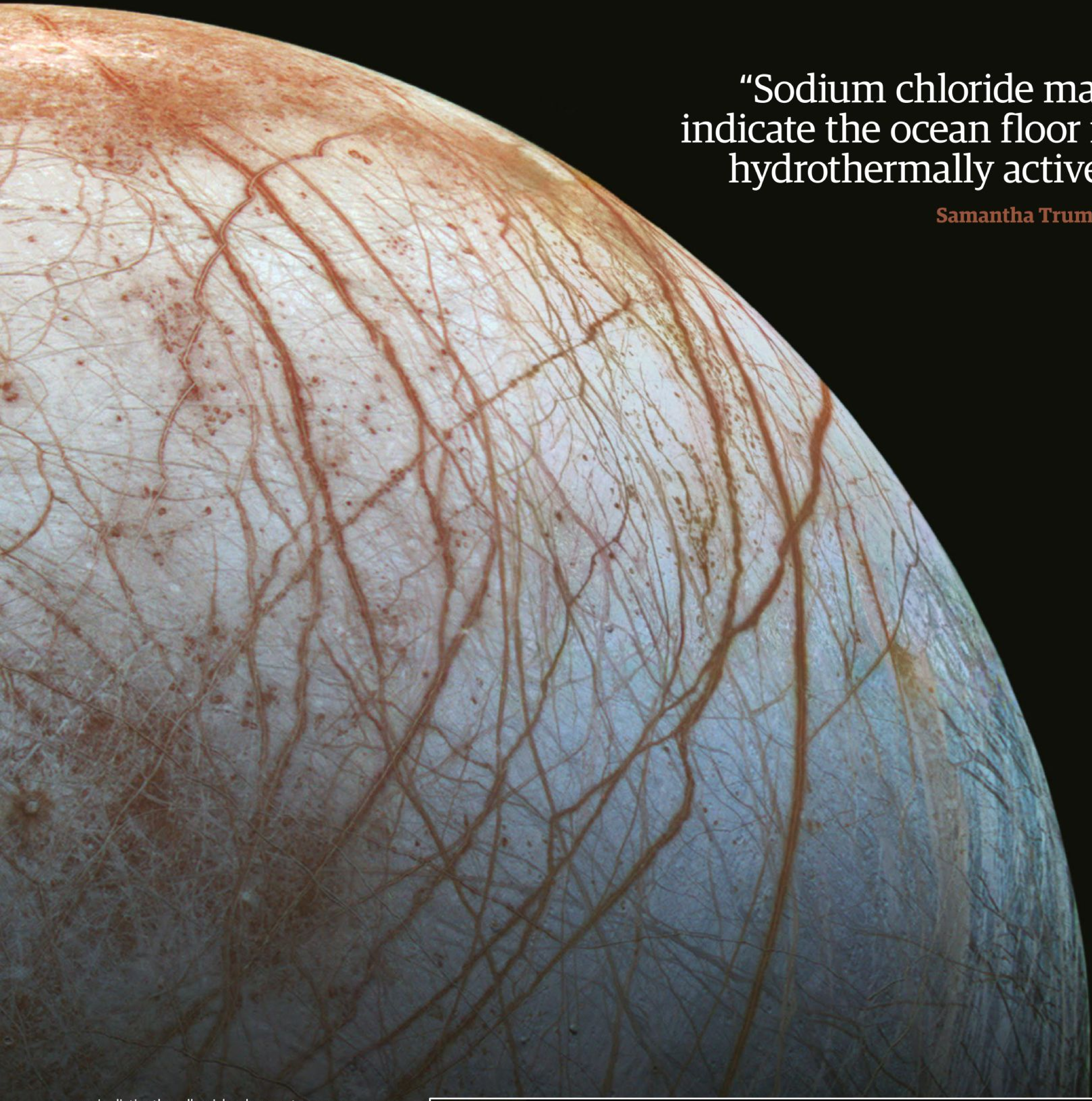
Europa, one of Jupiter's Galilean moons, has held the attention of astronomers since its up-close inspection by NASA's Voyager 1 spacecraft in 1979. Since that flyby analysis of the moon has painted the picture that beneath the icy crust is a salty, subsurface ocean – possibly similar to Earth's oceans. Now astronomers at Caltech and NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, United States, have found sodium chloride – more commonly known as table salt – resting on the surface. This could have positive implications for Europa's oceans, as table salt is also the main compound of sea salt on Earth.

NASA's aforementioned Voyager flyby was later followed by NASA's Galileo spacecraft in 1997. Galileo was able to obtain up-close data of Europa using its near-infrared spectrometer. This spectrometer splits up the near-infrared light reflecting off the surface of the icy moon in order to tell astronomers what the surface is composed of. This analysis revealed that the surface showed signs of water-ice and what were believed to be magnesium sulphates, which are similar to Epsom bath salts.

Astronomers took this analysis at face value and not many questioned it. However, recently Caltech and JPL decided to take spectrometer data of the moon in visible light. This high-resolution data was obtained using the W. M. Keck Observatory that sits on the dormant volcano Mauna Kea in Hawaii. After the recent inspection astronomers found that there wasn't actually any sign of magnesium sulphates. This had them scratching their heads in confusion. "We thought that we might be seeing sodium chlorides, but they are essentially featureless in an infrared spectrum," says Mike Brown, the Richard and Barbara Rosenberg professor of planetary astronomy at Caltech.

At this point Kevin Hand, a scientist at JPL, took sample ocean salts and applied them to Europa-like conditions. This essentially means they bombarded it with radiation. From this Hand discovered that the salts had an interesting reaction to the radiation, most interesting of which was them beginning to appear yellowish and becoming detectable in the visible-light spectrum. This drew comparisons to the analysis of Europa, explaining why its Tara Regio

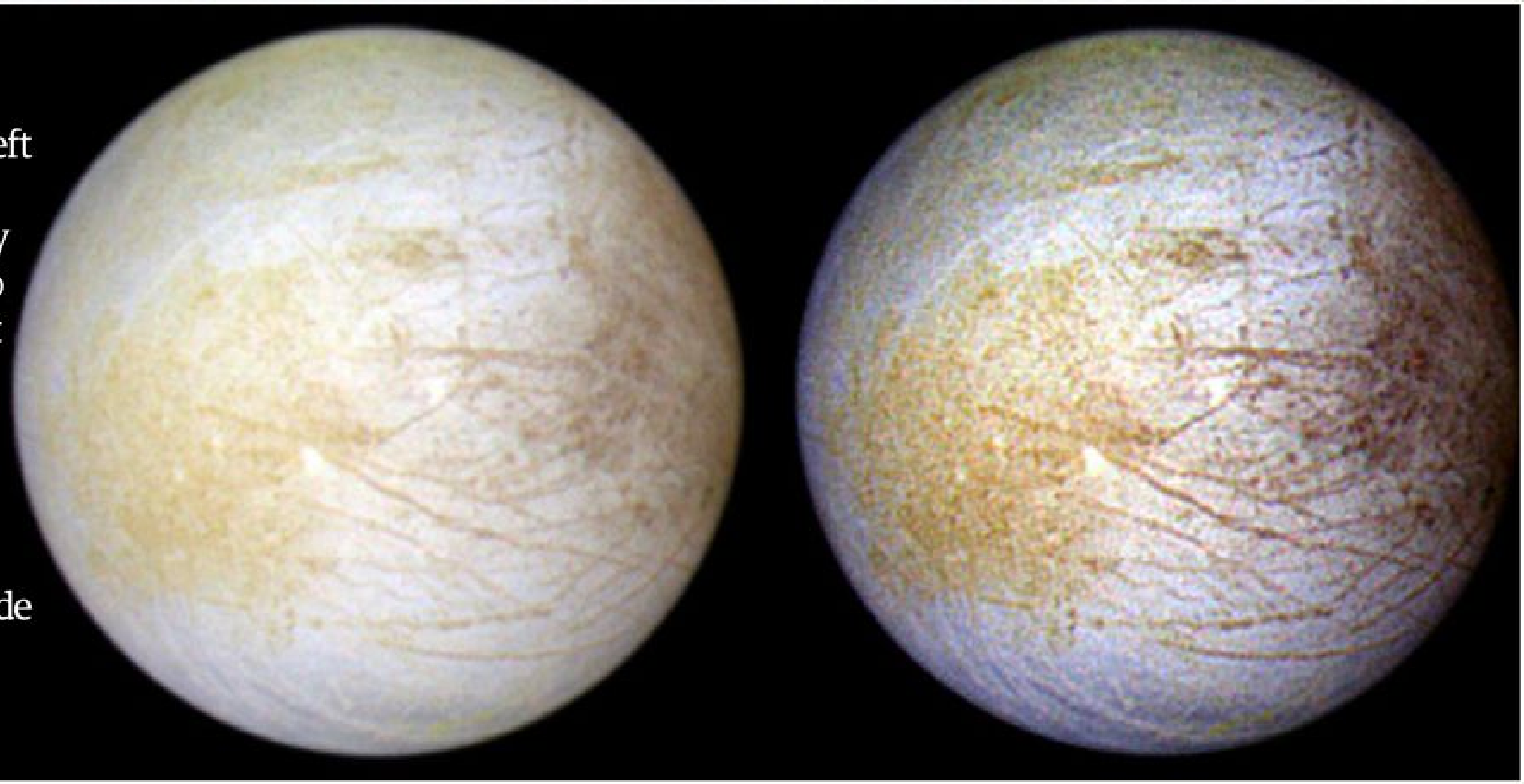
> “Sodium chloride may indicate the ocean floor is hydrothermally active”
>
> **Samantha Trumbo**



area is distinctly yellowish where astronomers were originally unable to detect the sodium chloride.

After this realisation, NASA/ESA’s Hubble Space Telescope was called into action to have a look at the Tara Regio using its visible-light spectrometer and confirmed the presence of table salt. "We've had the capacity to do this analysis with the Hubble Space Telescope for the past 20 years," Brown said. "It's just that nobody thought to look."

“Magnesium sulphate would simply have leached into the ocean from rocks on the ocean floor, but sodium chloride may indicate the ocean floor is hydrothermally active,” says Samantha Trumbo, the lead of the study and a graduate student at Caltech. "That would mean Europa is a more geologically interesting planetary body than previously believed."



Right: Tara Regio, the region to the left of the centre, was imaged by NASA’s Galileo spacecraft, but astronomers have only recently identified a profusion of sodium chloride

© NASA/JPL-Caltech

Even in its old age the Sun has been exhibiting superflares

OUR AGING SUN

Should we worry about its supeflares?

Reported by Elizabeth Howell

IN COOPERATION WITH SPACE.com

The mature Sun may still be prone to temper tantrums. A new study suggests that older stars like the Sun can produce superflares – huge bursts of energy visible across hundreds of light years.

Superflares used to be thought of as a younger-star phenomenon, researchers said in a statement about the new study, but the new work suggests it can happen on the Sun at rare intervals, perhaps once every few thousand years.

The Sun is hard to predict on even a daily basis, so it's difficult to say when a superflare would occur. However, the new work's lead scientist, Yuta Notsu, a visiting researcher at the University of Colorado Boulder, said this possibility should inspire everyone to beef up electronics against radiation.

"If a superflare occurred 1,000 years ago, it was probably no big problem. People may have seen a large aurora," Notsu said in a statement, referring to the dancing northern or southern lights produced by solar particles interacting with molecules of Earth's atmosphere. "Now it's a much bigger problem because of our electronics."

We already know the power of the Sun can knock out power lines, electronics and satellites. Coronal mass ejections from the Sun – or large plumes of charged particles – have caused issues with our infrastructure in the past, such as the extraordinary 1859 Carrington Event superstorm that affected telegraph communications. A superflare, however, would be worse. The superflare would be hundreds or thousands of times more powerful than the most active solar flares recorded.

"If a superflare erupted from the Sun… Earth would likely sit in the path of a wave of high-energy radiation. Such a blast could disrupt electronics across the globe, causing widespread blackouts and shorting out communication satellites in orbit," representatives from the University of Colorado Boulder said in the statement.

The new superflare data came from NASA's Kepler space telescope, which looked for planets at faraway stars between 2009 and 2018. While looking for new worlds, Kepler also saw a lot of star activity. It spotted a few superflares, moments when the starlight would suddenly get brighter before dimming again.

Curious about Kepler's findings, the researchers looked to the European Space Agency's Gaia spacecraft – which studies stellar movements and brightnesses across a billion stars – and the Apache Point Observatory in New Mexico.

The two telescopes saw 43 superflares that came from stars similar in age and size to our own Sun. Statistics from their data show that most superflares do come from younger stars, which can flare about once a week. Our own Sun is still prone, but just once every few thousand years.

> "The Sun is hard to predict on even a daily basis, so it's difficult to say when a superflare would occur"

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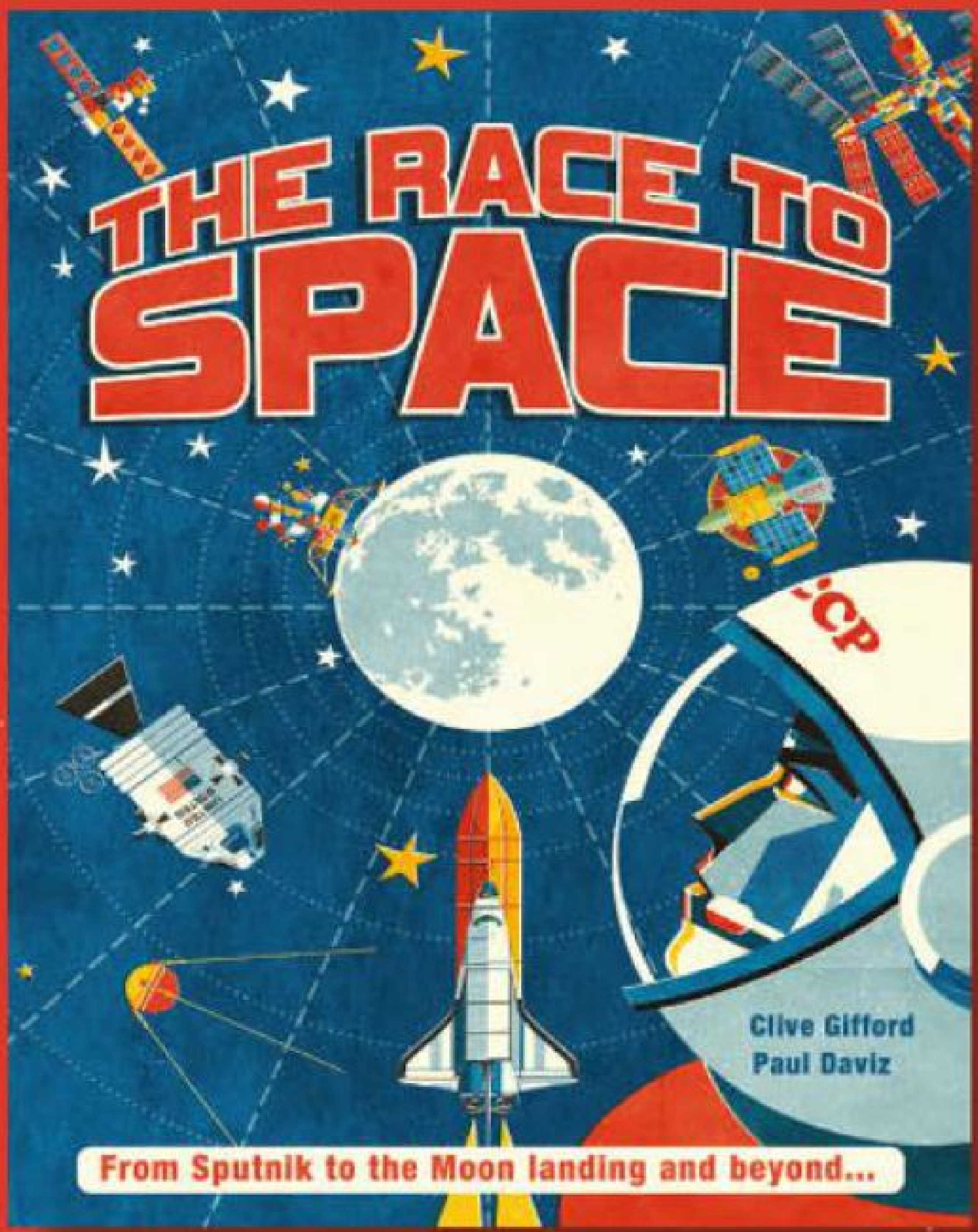

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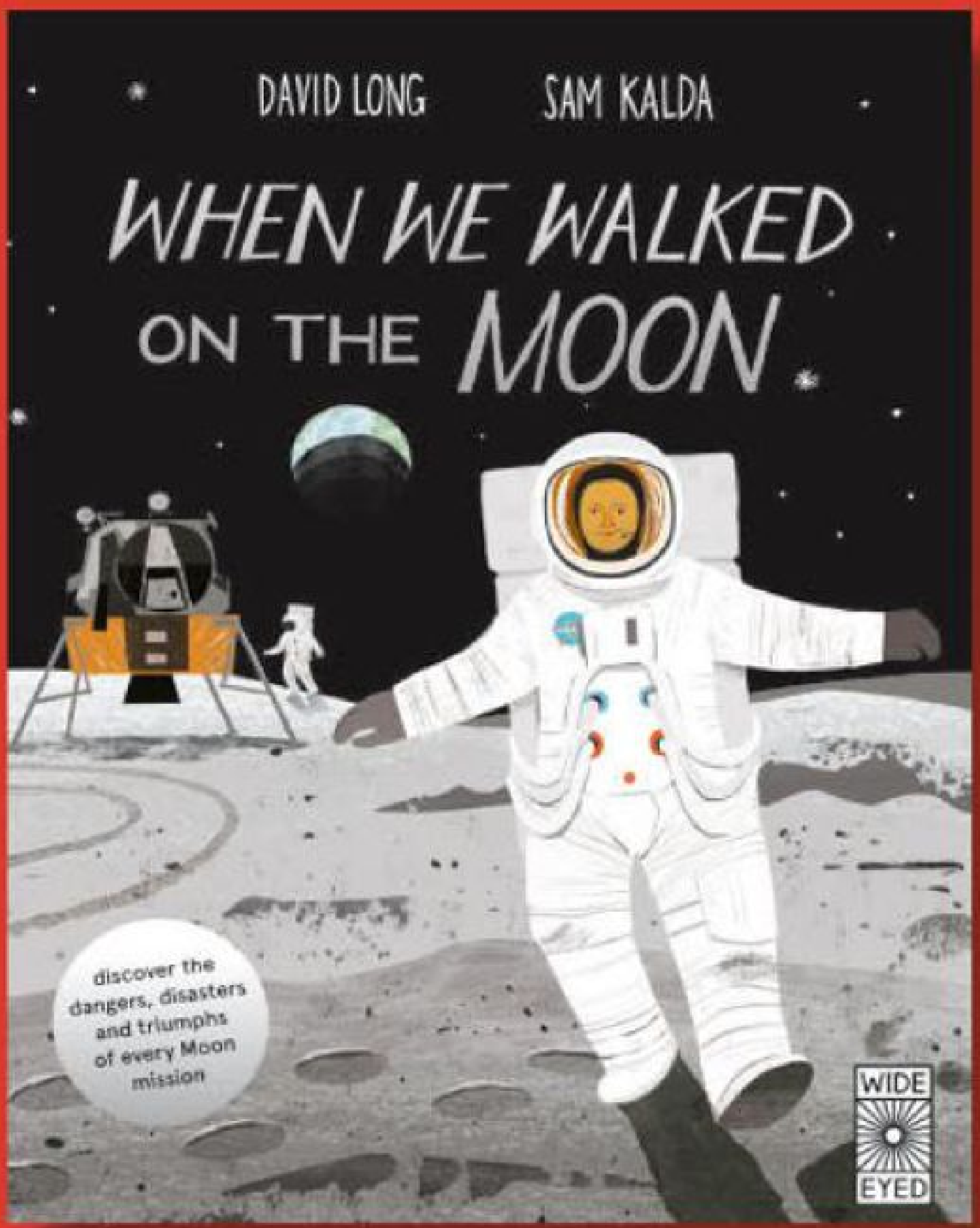

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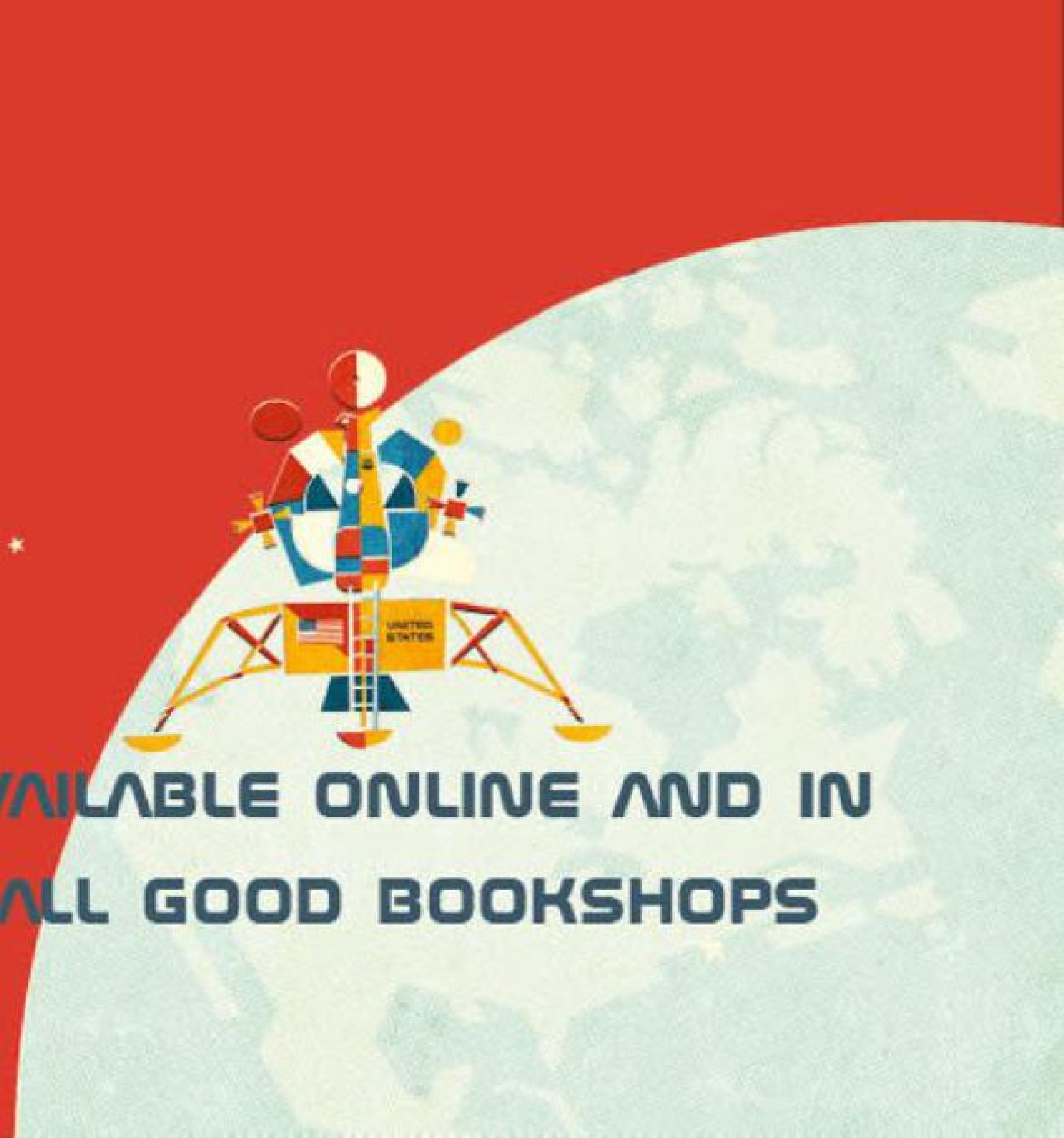

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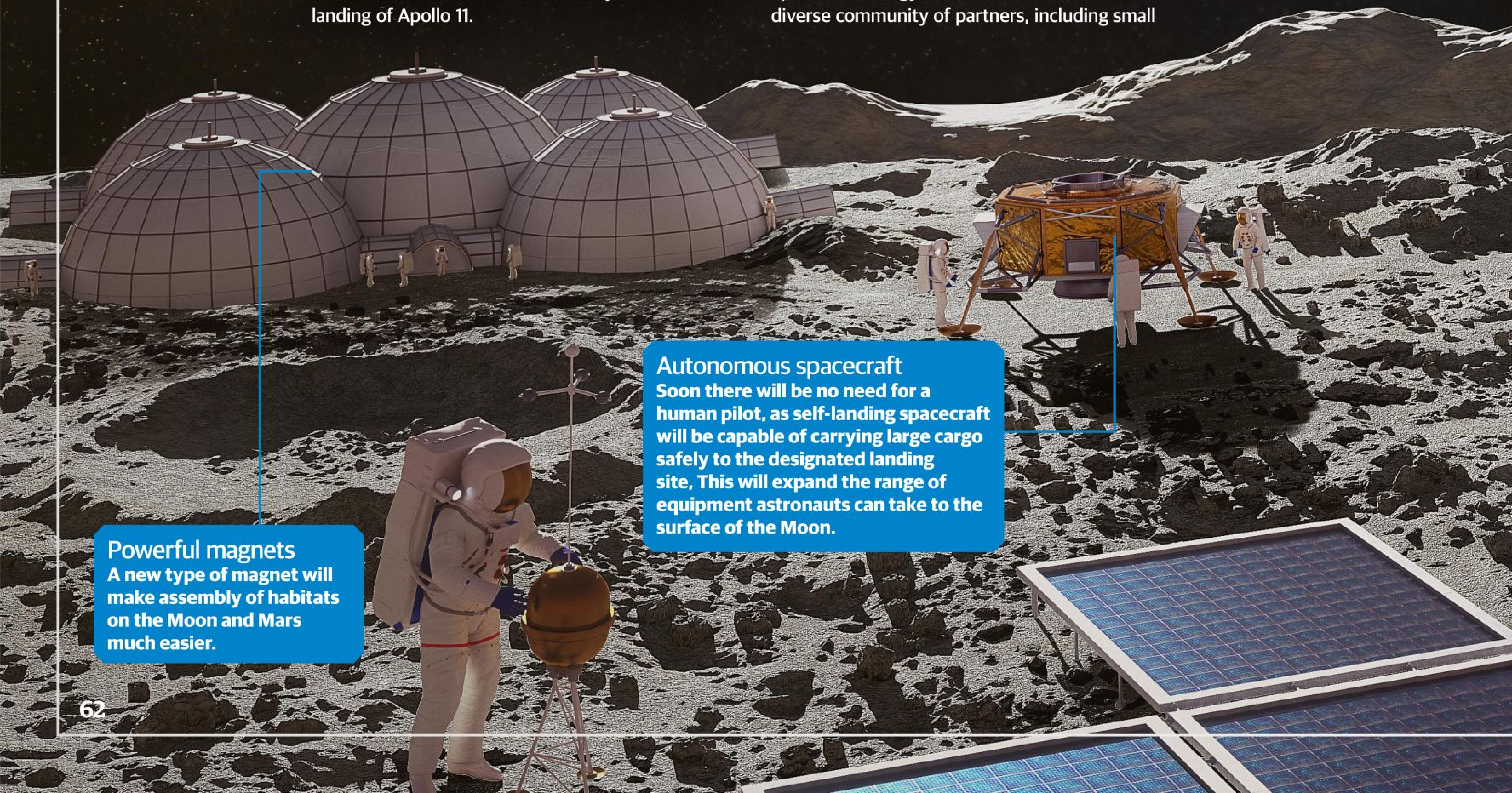
THE FUTURE OF LUNAR LANDINGS

NASA has funded a host of small businesses developing new technology that can make landing on the Moon safer and more reliable than ever

NASA continues to actively seek out technologies that can make every aspect of lunar exploration easier, more accessible and more reliable. Recently the government agency awarded a grand total of $106 million (approximately £84 million) to 129 small businesses in the United States to develop their own exciting space exploration technologies, which will include self-landing spacecraft to fold-out solar panels. The 142 accepted proposals will not only stimulate the United States' economy with small business involvement, but the world can witness the amazing technological advancements that have occurred over the last 50 years since the landing of Apollo 11.

This initiative comes courtesy of NASA's Small Business Innovation Research (SBIR) program, and this cash injection is the reward for these businesses reaching its second phase. The first phase saw the initial introduction of the technology looking to prove its feasibility, whereas this second phase is all about the three Ds – development, demonstration and delivery. The third and final phase will be the commercialisation of the innovative products.

"Small businesses play an important role in our science and exploration endeavours," says Jim Reuter, acting associate administrator of NASA's Space Technology Mission Directorate. "NASA's diverse community of partners, including small



Autonomous spacecraft
Soon there will be no need for a human pilot, as self-landing spacecraft will be capable of carrying large cargo safely to the designated landing site, This will expand the range of equipment astronauts can take to the surface of the Moon.

Powerful magnets
A new type of magnet will make assembly of habitats on the Moon and Mars much easier.

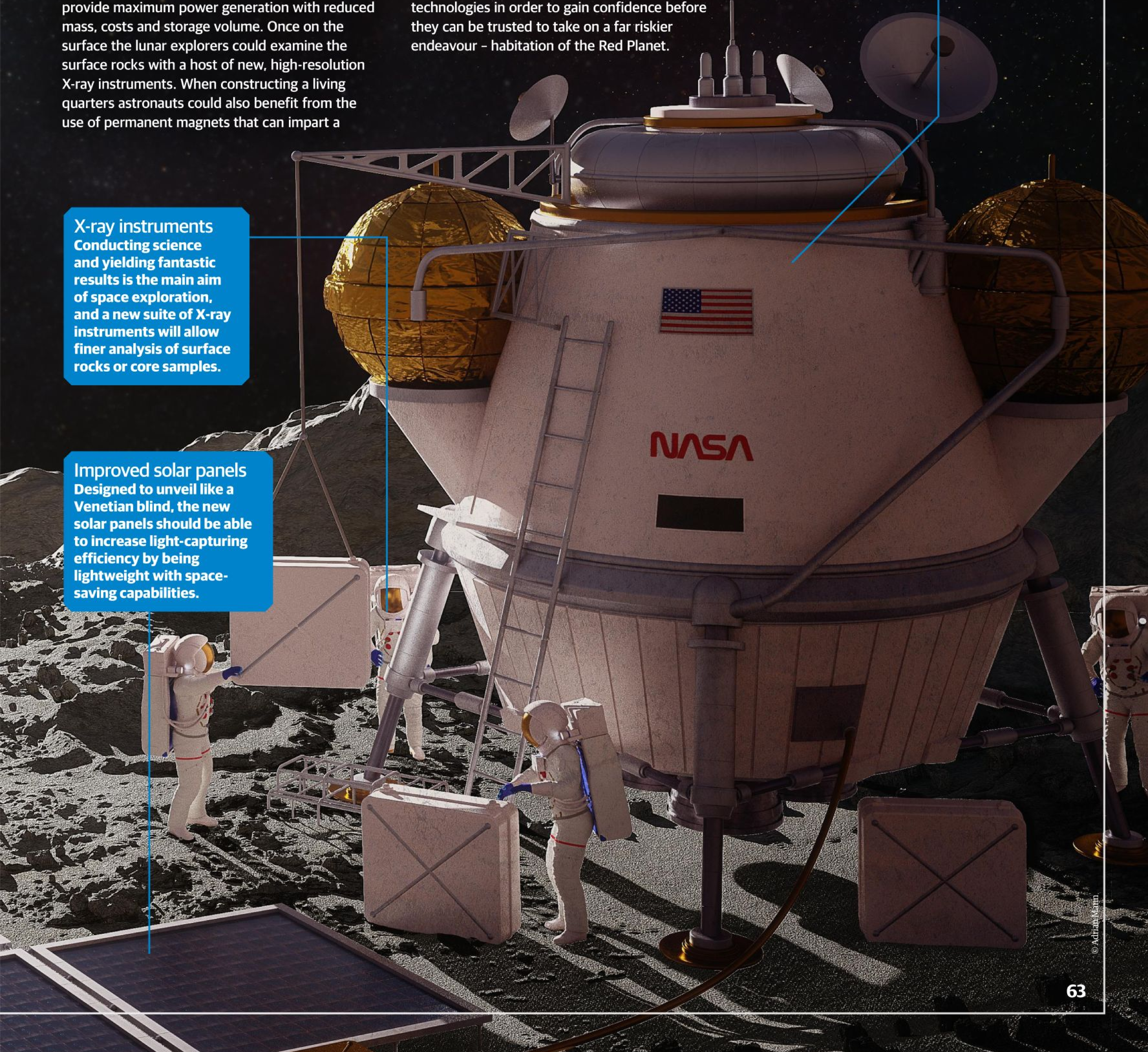
businesses across the country, help us achieve our mission and cultivate the US economy. Their innovations will help America land the first woman and the next man on the Moon in 2024, establish a sustainable presence on the lunar surface a few years later and pursue exciting opportunities for going to Mars and beyond."

These proposals will cover a range of areas that are essential in landing on, exploring and leaving the Moon's surface. For instance, there are technologies that are being developed that could provide an autonomous landing on the lunar surface. This would allow astronauts to undergo a safer landing of their spacecraft, or even space cargo, to a landing site with minimal fuss.

When the astronauts have touched down they could have a new brand of solar panels that will provide maximum power generation with reduced mass, costs and storage volume. Once on the surface the lunar explorers could examine the surface rocks with a host of new, high-resolution X-ray instruments. When constructing a living quarters astronauts could also benefit from the use of permanent magnets that can impart a powerful bond between platforms and allow added security when putting tents, habitats or bases up. Although it is virtually impossible to eliminate all areas of risk, each of these technologies will provide a reduce in risk and an increase in productivity and sustainability.

All of these technologies could have implications not only for lunar exploration, but the exploration of Mars. With the eventual return to the Moon, astronauts and engineers need to test these technologies in order to gain confidence before they can be trusted to take on a far riskier endeavour – habitation of the Red Planet.

> "Small businesses play an important role in our science and exploration endeavours" **Jim Reuter, NASA**



Sensor technology
With the help of sensor technology the entry, descent and landing of any spacecraft will be improved for the next generation of lunar landers.

X-ray instruments
Conducting science and yielding fantastic results is the main aim of space exploration, and a new suite of X-ray instruments will allow finer analysis of surface rocks or core samples.

Improved solar panels
Designed to unveil like a Venetian blind, the new solar panels should be able to increase light-capturing efficiency by being lightweight with space-saving capabilities.

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BEYOND DEEP SPACE

How technology is helping us peer to the edges of the observable universe

Reported by Abigail Beall

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From neutrinos produced just seconds after the Big Bang to the most distant superclusters of galaxies we know of, studying the edge of our universe is an exciting task for astronomers around the world. And thanks to advancements in technology, we know more than ever about what lies at the boundaries of our cosmos.

When you look at something, you are looking back in time. This holds true for anything you see, it's just the distances involved are mostly so small and light moves so quickly, you will never notice the time it takes to reach you. When you begin to look into space, the time difference starts to matter. Looking at the Moon, you are seeing it about 1.3 seconds back in time. Light takes just over eight minutes to reach us from the Sun, and to Jupiter it's about 43 minutes.

However, these kinds of time scales are nothing compared to the amount of time it's taken light to reach Earth from the most distant stars and galaxies we can see.

Based on calculations, astronomers believe the universe is 13.8 billion years old. Light moves at the speed of light, travelling 299,792 kilometres (186,282 miles) every second. In one year light travels the distance of one light year, or 9.46 trillion kilometres (5.88 trillion miles). It sounds like a huge number, but in the scale of the universe one light year is nothing. This means even with the most powerful telescopes, there is a limit to how far away we can see based on the time it takes light to reach us. This means there's a sphere around Earth, beyond which we simply cannot see. This is called the observable universe.

To complicate matters, the universe is also expanding, and accelerating in its rate of expansion too. This means since light was released 13.8 billion years ago, the position from which that light came has now moved further away. In astronomy, this is known as the comoving distance. Astronomers estimate the distance to the edge of the observable universe is 45.7 billion light years.

The most distant confirmed galaxy we know of is called GN-z11, and it is an estimated 32 billion light years from Earth. It was first imaged by the Hubble Space Telescope. After that there is MACS1149-JD1, at 30 billion light years. The most distant object that is not a galaxy is a gamma-ray burst, seen at 13.18 billion light years away, detected in April 2009.

But peering to the galaxies and gamma-ray bursts at the edge of the universe is by no means the only way to find out more about the early stages of the universe.

One method used by astronomers to peer to the edge of the universe is by studying the Cosmic

Microwave Background (CMB). The CMB is electromagnetic radiation that has been left over from an early stage in the universe's lifetime, about 380,000 years after the Big Bang, and for that reason it's also referred to as an echo of the Big Bang. It was first discovered in 1964, by accident, when Arno Penzias and Robert Wilson were using a telescope in the microwave range and noticed interference coming from every part of the sky.

"When we first heard that inexplicable 'hum,' we didn't understand its significance, and we never dreamed it would be connected to the origins of the universe," Penzias said in a statement. "It wasn't until we exhausted every possible explanation for the sound's origin that we realised we had stumbled upon something big." It was big indeed, and in 1978 the pair won the Nobel Prize for their discovery.

Looking at the CMB, astronomers can learn about a time just after the Big Bang, when photons were first able to move around freely. It looks roughly the same in any direction you look. Then, between 2009 and 2013 the European Space Agency's Planck observatory undertook the most detailed study of the CMB to date. In a paper published in June this year, a new analysis of this data shows anomalies, like a cold spot, which astronomers are still struggling to explain.

Although the CMB gives us unique insight into the early stages of the universe, there are other ways to find out about what lies at the edges of our observable universe.

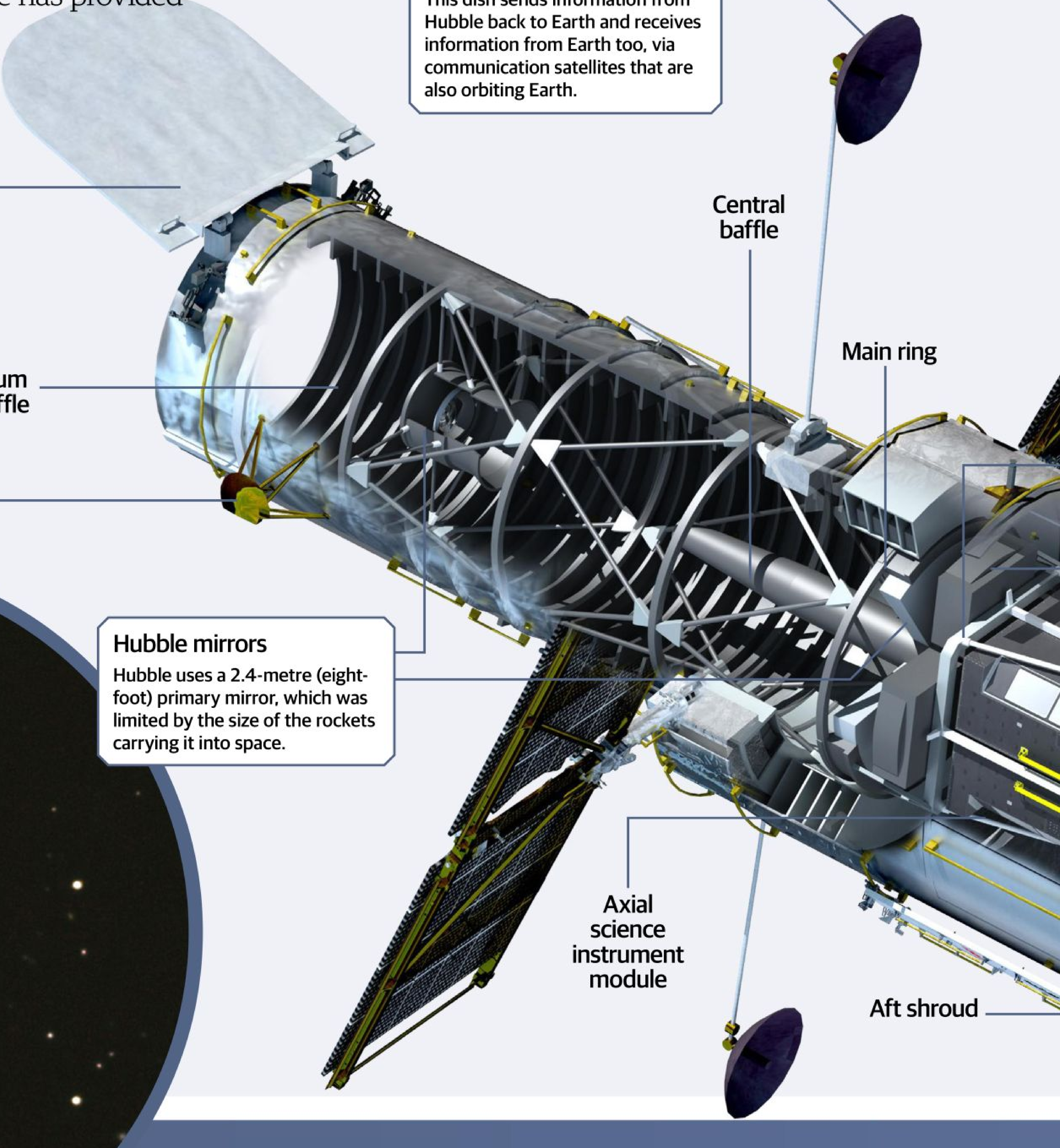
In June 2018, a group of astronomers announced a discovery that challenges assumptions researchers had made about the early history of the universe. The team, led by Scott Chapman at Dalhousie University in Canada, were able to find a supercluster of 14 galaxies 90 per cent of the way to the edge of the observable universe. Called a galactic protocluster, the 14 galaxies are a precursor to galaxy clusters, the largest known objects in the universe. These galaxies were seen 12.4 billion light years away, only 1.4 billion years after the start of the universe.

According to previous models of how the universe evolved, protoclusters like this were not expected to have existed as early as then. The discovery of the cluster, called SPT2349-56, proved the evolution of galaxy clusters happens

> “We didn't understand its significance, and we never dreamed it would be connected to the origins of the universe” **Arno Penzias**

The Hubble Space Telescope

Launched in 1990, Hubble has provided us with years of science

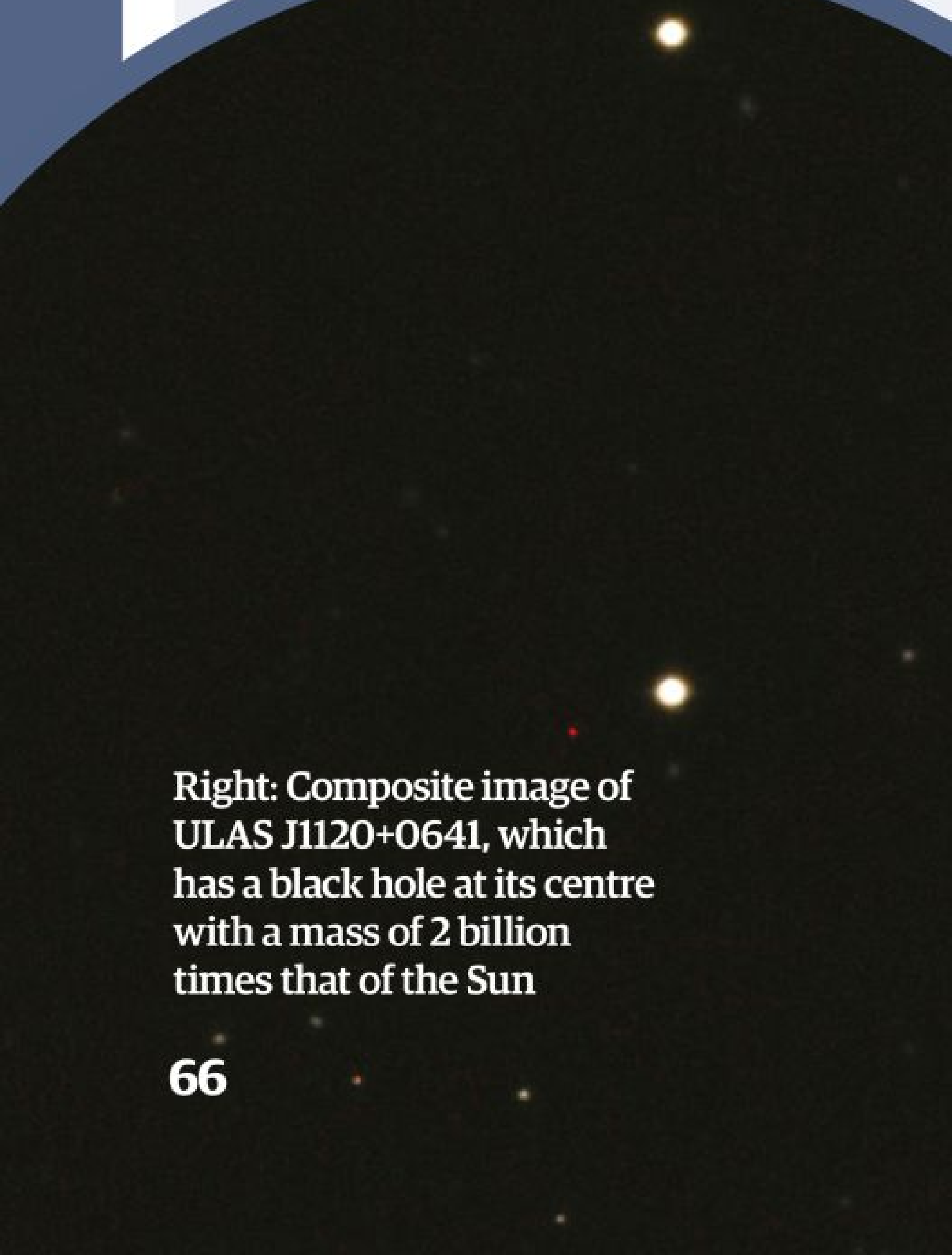


Communications antennae
This dish sends information from Hubble back to Earth and receives information from Earth too, via communication satellites that are also orbiting Earth.

Light shield
This prevents unwanted light from entering the telescope and messing with the images taken by the extremely sensitive instruments.

Hubble mirrors
Hubble uses a 2.4-metre (eight-foot) primary mirror, which was limited by the size of the rockets carrying it into space.

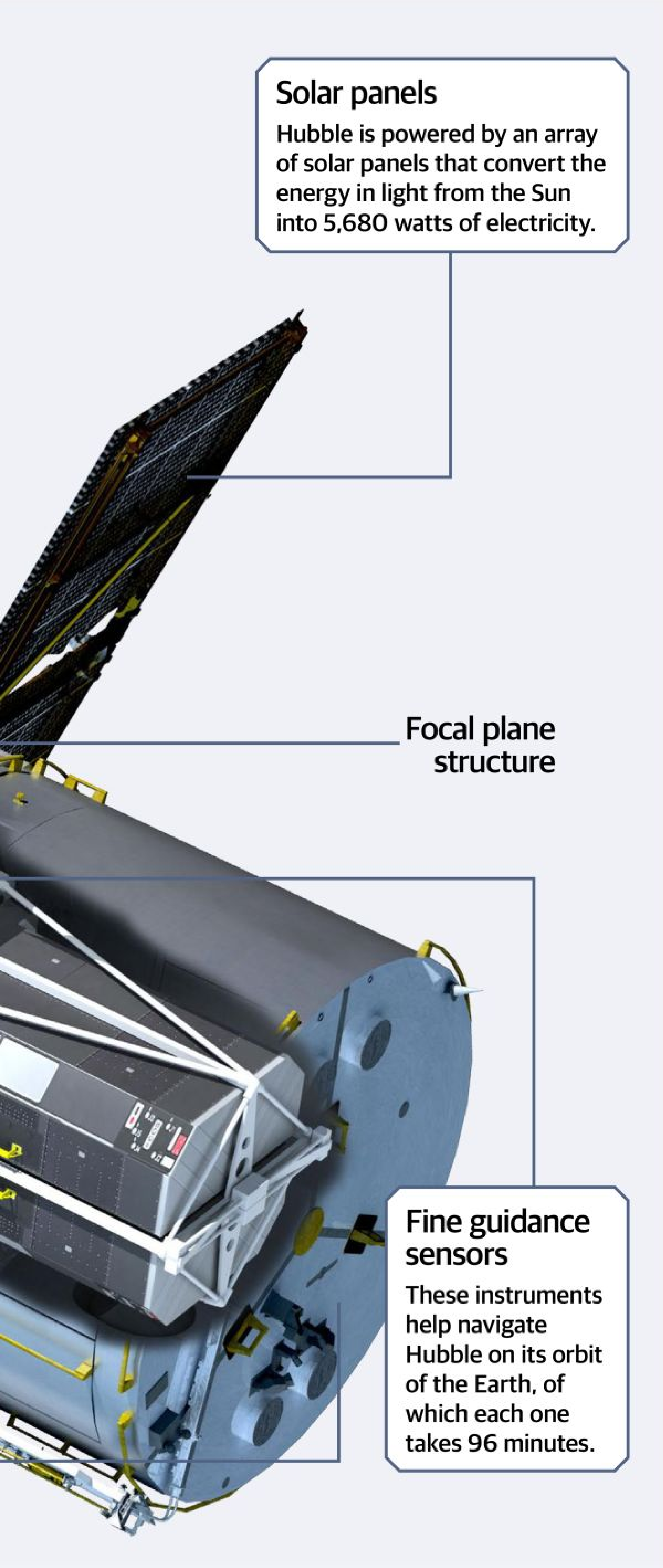
© ESO, Illustration by Adrian Mann



Right: Composite image of ULAS J1120+0641, which has a black hole at its centre with a mass of 2 billion times that of the Sun much more quickly than astronomers had previously believed.

Chapman says the only way he and his team were able to make this discovery was because of technology. "The South Pole Telescope is how we discovered it, and the upgrades going on, called SPT-3G, will enable more of these types of discoveries," he says. The South Pole Telescope is a ten-metre (33-foot) diameter telescope at the Amundsen-Scott South Pole Station in Antarctica. It looks in the microwave, millimetre, and sub-millimetre ranges of electromagnetic radiation, and was originally designed for observing the CMB. The third generation of the telescope was installed in 2017, including ten-times the number of sensors, which means it can map a section of the sky ten-times faster than before. In 2018, a new survey began using this new camera.

"But SPT couldn't do it on its own," says Chapman. "Other ESO [European Southern



Solar panels

Hubble is powered by an array of solar panels that convert the energy in light from the Sun into 5,680 watts of electricity.

Focal plane structure

Fine guidance sensors

These instruments help navigate Hubble on its orbit of the Earth, of which each one takes 96 minutes.

Picture gallery: beyond deep space

Looking out as far as we can, astronomers have found galaxies almost as old as the universe itself

GN-z11 is a high-redshift galaxy found in the constellation Ursa Major. GN-z11 is currently the oldest and most distant known galaxy in the observable universe.

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When GRB 090423, seen here as an artist's impression, was detected it was a signature of the explosion of the earliest, most distant known object in the universe.

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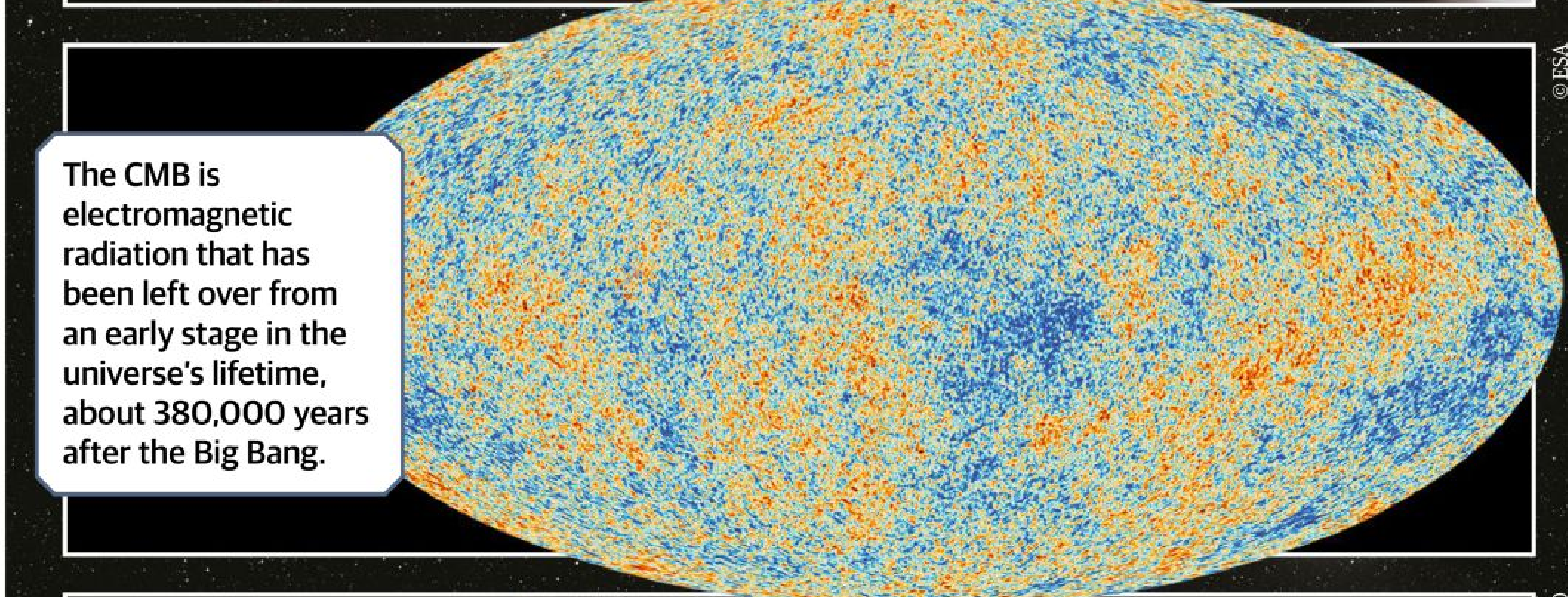

The CMB is electromagnetic radiation that has been left over from an early stage in the universe's lifetime, about 380,000 years after the Big Bang.

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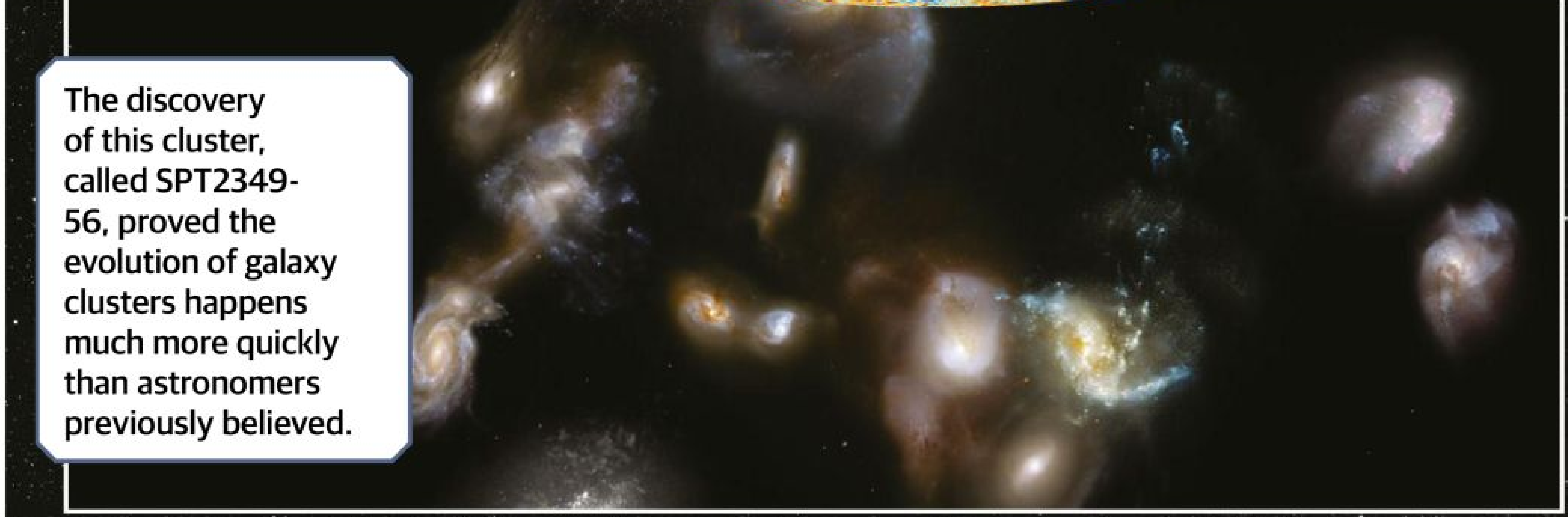

The discovery of this cluster, called SPT2349-56, proved the evolution of galaxy clusters happens much more quickly than astronomers previously believed.

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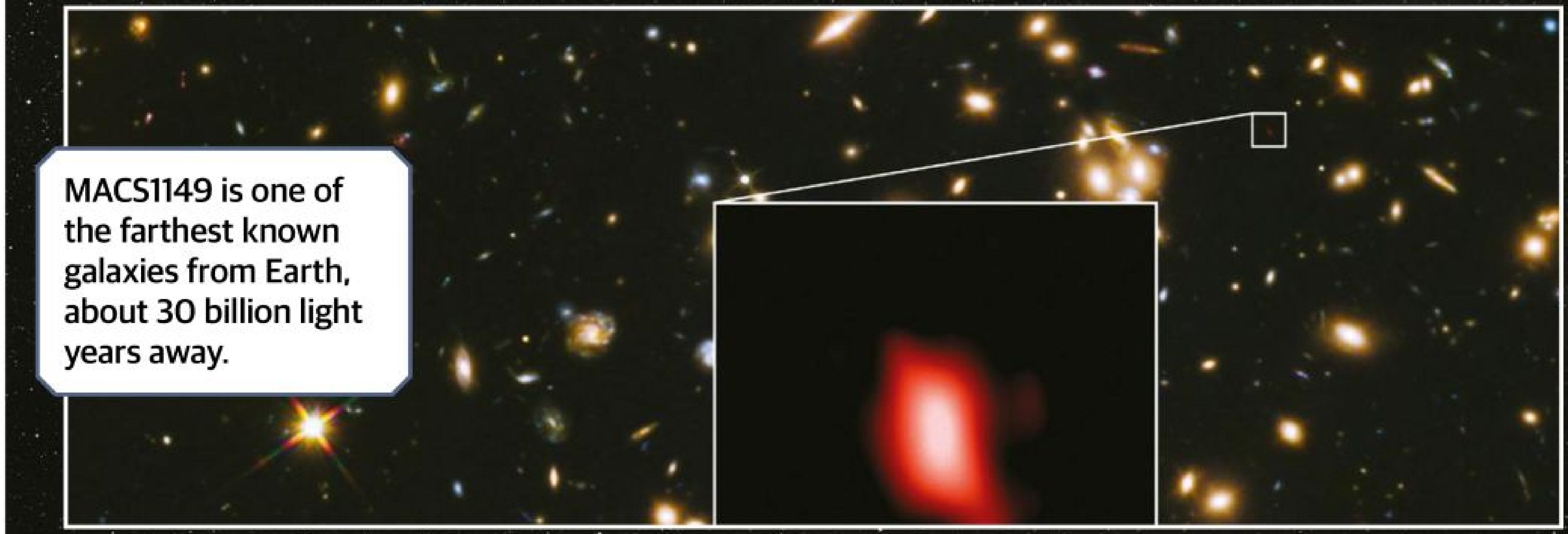

MACS1149 is one of the farthest known galaxies from Earth, about 30 billion light years away.

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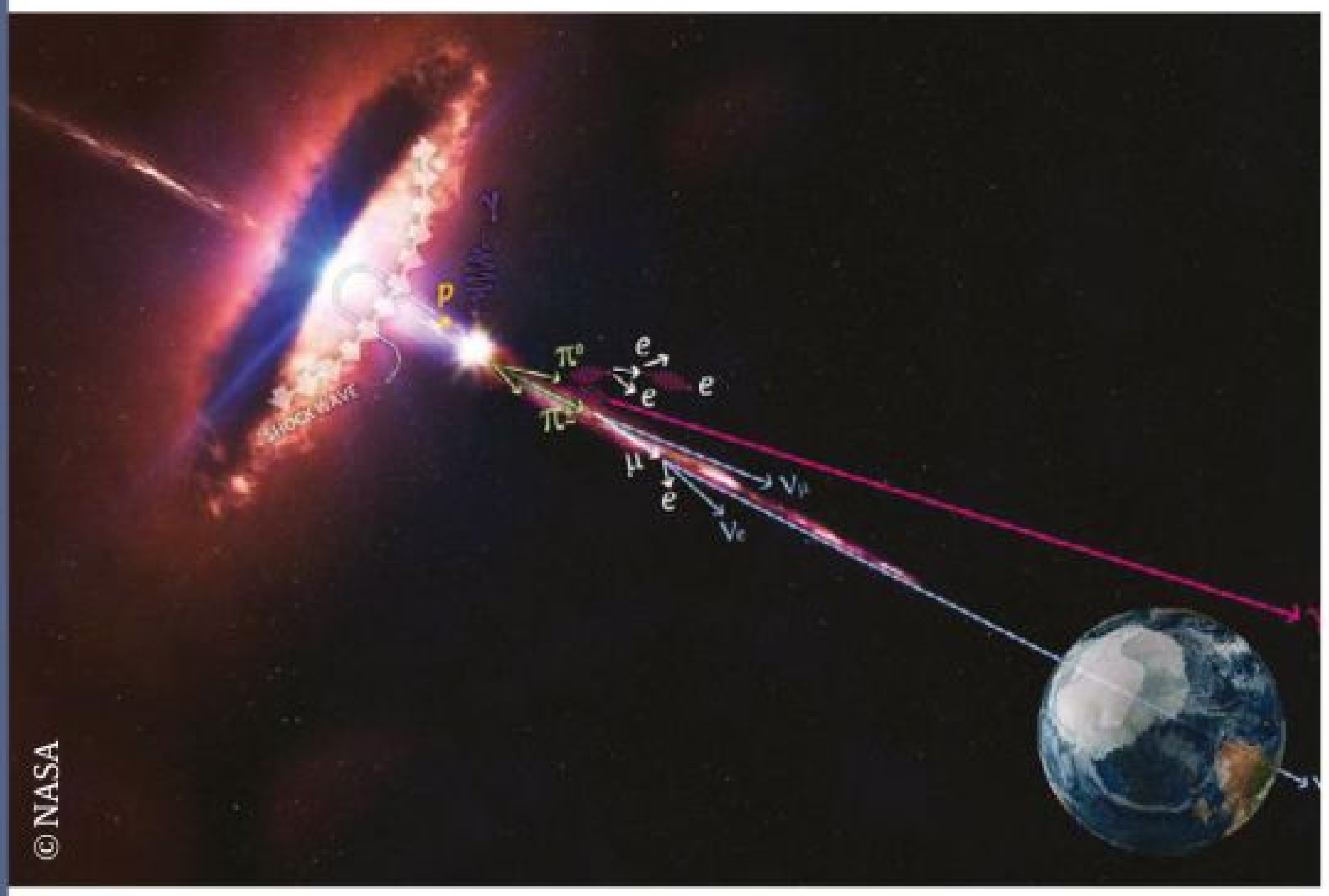
Observatory] and international facilities were the keys to unlocking the details of this and other superclusters near the edge of the observable universe." These include the Atacama Pathfinder Experiment (APEX) and the Atacama Large Millimeter/submillimeter Array (ALMA), both based in the Atacama desert of northern Chile. ALMA is an interferometer made up of 66 radio telescopes working together, sitting at 5,058 metres (16,600 feet) above sea level, while APEX is a radio telescope at an elevation of 5,100 metres (16,730 feet). Chapman is excited about technological developments in this region, too.

"A new telescope going high above ALMA in Chile, CCAT [Cerro Chajnantor Atacama Telescope], will also permit new ambitious surveys that will open up the discovery of space even more," he says. The six-metre (19.7-foot) telescope is designed to observe at submillimetre to millimetre wavelengths and will be built in the Atacama desert at an elevation of 5,600 metres (18,400 feet). The telescope, which will be roughly 12-metres (39.4-feet) tall, is expected to gather its first light in 2021.



© NASA

Chapman is expecting to publish an update to his study soon, a detailed follow-up of the previous study. While it's not yet published, we can be sure it's going to be an exciting announcement.

Due to be completed in 2021, NASA's James Webb Space Telescope is also hoping to study the galaxies that formed in the earliest universe. It is extending the work done by the Hubble Space Telescope and will be looking at longer wavelengths of light than its predecessor. The telescope's main focus will be the time during which most galaxies began to form, which will hopefully help answer the questions brought about by studies like Chapman's and shine light on how galaxy formation happens.

But it's not all about light. Studying neutrinos, fundamental particles that barely interact with anything, only through the weak force and gravity, can teach us about the edge of the universe too.

In March this year, Daniel Green from the University of California San Diego led a study using neutrinos as 'messengers from the early universe'. In the hot gas that filled the early universe, neutrinos travelled near the speed of light while everything else moved more slowly. They are uniquely placed to teach us about that stage of the universe.

"We looked for the signal of cosmic neutrinos in distribution of galaxies in the universe" says Green. "We used data from one particular survey, BOSS, which measured the locations of approximately 1 million galaxies very precisely." The Baryon Oscillation Spectroscopic Survey (BOSS) was part of the third Sloan Digital Sky Survey and gathered data from 2009 to 2014 at the Apache Point Observatory in New Mexico, United States.

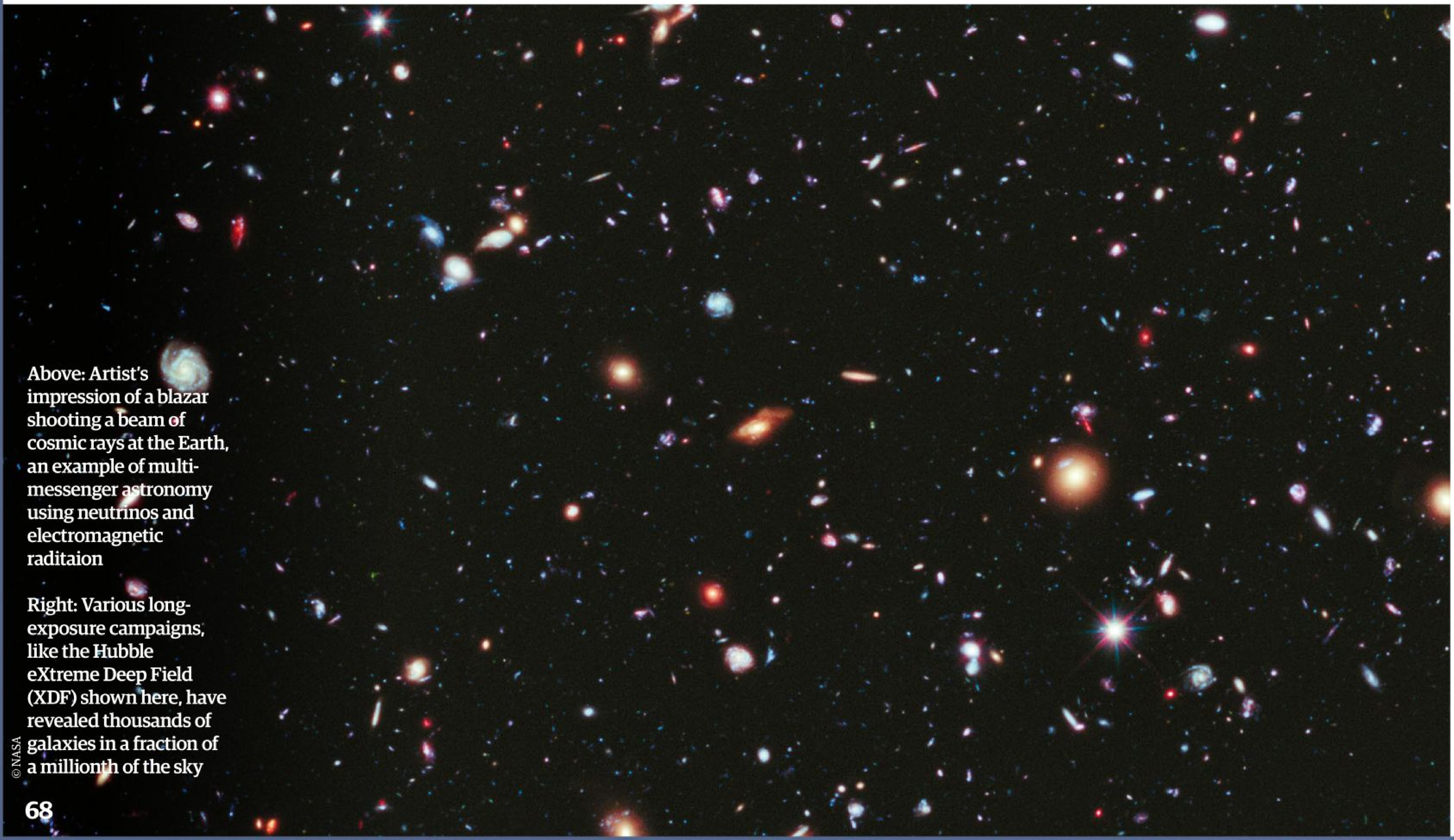
Because of the high speeds they moved at, the neutrinos affected how matter moved on very large distances. Green and his colleagues isolated a signal in the galaxies that could only have been caused by a particle moving at the speed of light in the early universe. This means the neutrino was the only option for the cause of these signals.

The cosmic neutrinos are imprinted in the locations of the galaxies found during the observations. From studying the neutrinos the astronomers can tell where they came from. "We used a new type of data analysis technique, built on earlier work, to extract the signal of the neutrinos from these maps of the universe" Green says.

There are many approaches to making maps of the universe and different technologies that make them possible. "The most important thing with this particular survey is that it can measure the spectrum of a large number of galaxies, which gives very accurate measurements of the distances," says Green.

The results from this study confirm the idea that the universe was heated to a very high temperature and then cooled through expansion. "In particular,

"A new telescope in Chile will permit new ambitious surveys that will open up the discovery of space even more" **Scott Chapman**



Above: Artist's impression of a blazar shooting a beam of cosmic rays at the Earth, an example of multi-messenger astronomy using neutrinos and electromagnetic raditaion

Right: Various long-exposure campaigns, like the Hubble eXtreme Deep Field (XDF) shown here, have revealed thousands of galaxies in a fraction of a millionth of the sky

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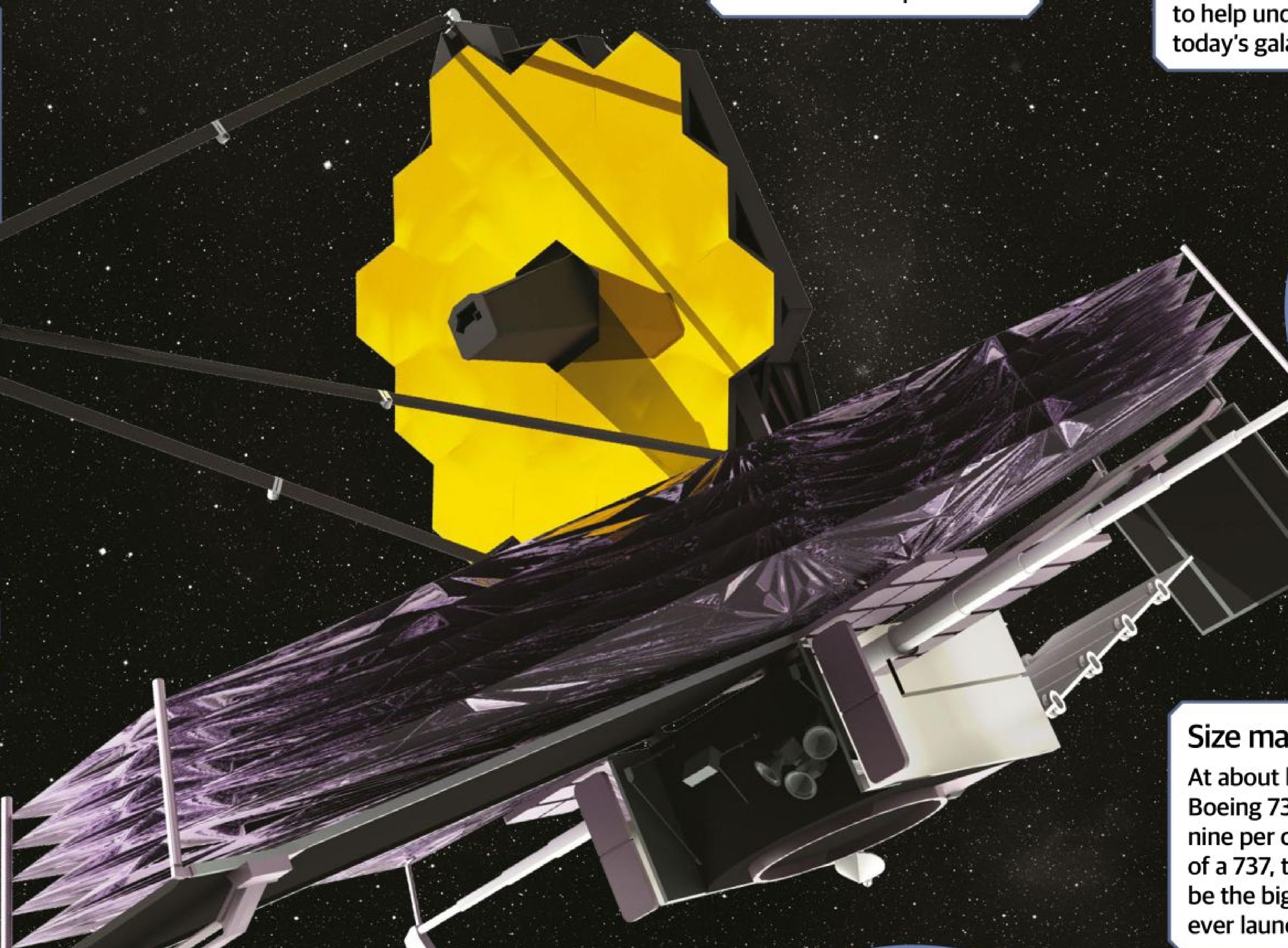
How the James Webb can

Expected to launch in 2021, the next-generation telescope will look at galaxies as they first formed



Infrared vision

The JWST will study the infrared part of the electromagnetic spectrum to peer back at galaxies over 13.5 billion years old.

A better mirror

The JWST's 18-segment primary mirror will be over six-times bigger in area than Hubble's and around 100-times more powerful.

Unprecedented sensitivity

The sensitivity of the instruments will allow astronomers to see the faintest, earliest galaxies to help understand how today's galaxies formed.

Size matters

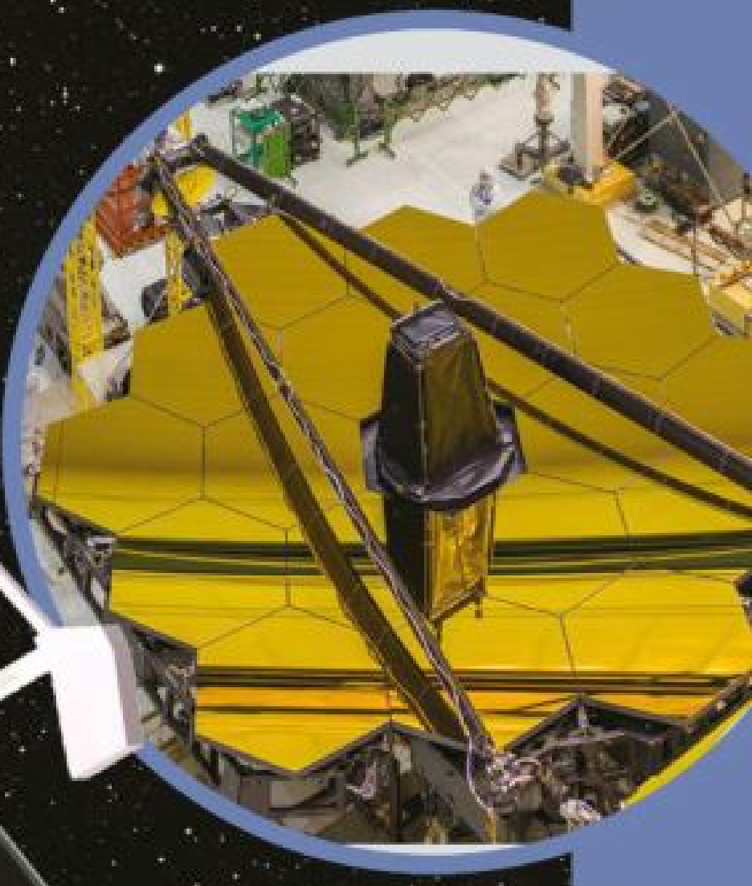
At about half the size of a Boeing 737, yet less than nine per cent of the mass of a 737, the JWST will be the biggest telescope ever launched into space.

A million miles away

The JWST will orbit the Sun, 1.5 million kilometres (1 million miles) from Earth, meaning its vantage point will be completely different to any before.

A collaboration

Over 1,200 skilled scientists, engineers and technicians from 14 countries have been involved with building the telescope.



© NASA; Illustration by Adrian Mann

this batch of neutrinos was released about a second after the Big Bang and is the earliest moment in the history of the universe, to date, where we have confirmed this story," says Green.

Data analysis is crucial in allowing advancements in astronomy, as the more information researchers gather, the more difficult it becomes to analyse that data. Increasingly, astronomers are relying on technology like artificial intelligence to help interpret and analyse data that would otherwise have taken researchers years to work through. Aside from improvements in the technologies used in the telescopes, this kind of technology is one of the most important areas in which astronomy research is developing.

There is a lot of hype about artificial intelligence. Whether it could bring us self-driving cars or be used to replace human jobs or to spy on members of the public, the possibilities of a future with AI are difficult to guess, and are often quite daunting. However, at least within astronomy, the technology is being used for good.

For example, a study in 2017 showed AI could be used to sift through data collected by gravitational wave detectors like the Laser Interferometer Gravitational-Wave Observatory (LIGO). These waves are ripples in space-time caused by large-scale events like the collision of two black holes. Using AI to help comb through data will enable more detections using multi-messenger astronomy – looking at the same event through multiple different signals including gravitational waves, electromagnetic radiation and neutrinos.

Together with improvements in technology regarding telescopes, like the upgrades to the South Pole Telescope and the new telescope in Chile, better data analysis techniques will enable astronomers to continue to peer as far back as possible and learn more about the distant universe in the next few years.

What could be at the edge of the universe?

Young galaxies

Peering to the edge of the observable universe gives us a unique insight into the very earliest days of the cosmos, a time when galaxies were just starting to form.

Superclusters

A study last year found a supercluster of 14 galaxies beginning to form together, making it the most distant supercluster ever discovered.

Neutrinos

Just seconds after the Big Bang, neutrinos were released, and now we can see them coming from distant galaxies to learn more about the early universe.

STARGAZER

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In this issue...

70 **What's in the sky?**
The shortest nights are now behind us, with new sights to look forward to

74 **Planets on display**
Saturn takes the spotlight, while Mercury, Venus and Mars are challenging targets

76 **Moon tour**
To the south of Plato are mountains worth exploring with a telescope

77 **Naked eye and binocular targets**
The Cygnus star cloud reveals millions of tiny stars

78 **Observe the Apollo landing sites**
Find the exact spots where history was made

84 **Deep sky challenge**
Glittering star clusters, a dead star's corpse and a beautiful double star to split

86 **The Northern Hemisphere**
A gaggle of galaxies, clusters and nebulae grace the skies

88 **Astrophotos of the month**
The best of our readers' excellent astrophotography

90 **Telescope review**
Is the Meade Polaris 114 EQ the right kit for you? We've tested it on your behalf

94 **Apollo girt guide**
Our pick of the best products celebrating the 50th anniversary of Apollo 11

What's in the sky?

21 JUL
The alpha-Cygnids reach their peak of five meteors per hour

26 JUL
The Capricornids reach their peak of five meteors per hour

29 JUL
The delta-Aquariids reach their peak of 20 meteors per hour

© Coconino National Forest

6 AUG
The tau-Aquariids reach their peak of eight meteors per hour

© Adam Block/Mount Lemmon SkyCenter/University of Arizona

6 AUG
Comet 168P/Hergenrother makes a close approach to the Sun, glowing at magnitude 11.5 in Taurus

9 AUG
Conjunction between the Moon and Jupiter in Ophiuchus

10 AUG
The Moon and Jupiter make a close approach, passing within 2°25′ of each other in Ophiuchus

© NASA

12 AUG
Asteroid 15 Eunomia is well placed for observation, glowing at magnitude 8.3 in Aquarius

© Brocken Inaglory

Red light friendly
In order to preserve your night vision, you should read our observing guide under red light

Jargon buster

Conjunction
A conjunction is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Right Ascension (RA)
Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

Declination (Dec)
This tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Magnitude
An object's magnitude tells you how bright it appears from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object. So, a magnitude of -1 is brighter than an object with a magnitude of +2.

Opposition
When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Greatest elongation
When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongations and as morning stars during western elongations.

31 JUL

The Piscis Astraliids reach their peak of five meteors per hour

2 AUG

The alpha-Capricornids reach their peak of five meteors per hour

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7 AUG

Asteroid 16 Psyche is well placed for observation in Capricornus

© Brocken Inaglory

10 AUG

Mercury reaches greatest elongation west, shining brightly at magnitude -0.1 in the morning sky

12 AUG

Mercury reaches highest point in the morning sky, shining brightly at magnitude -0.1

12 AUG

The Moon and Saturn make a close approach, passing within 0°02' of each other in Sagittarius

13 AUG

The Perseids reach their peak of 80 meteors per hour

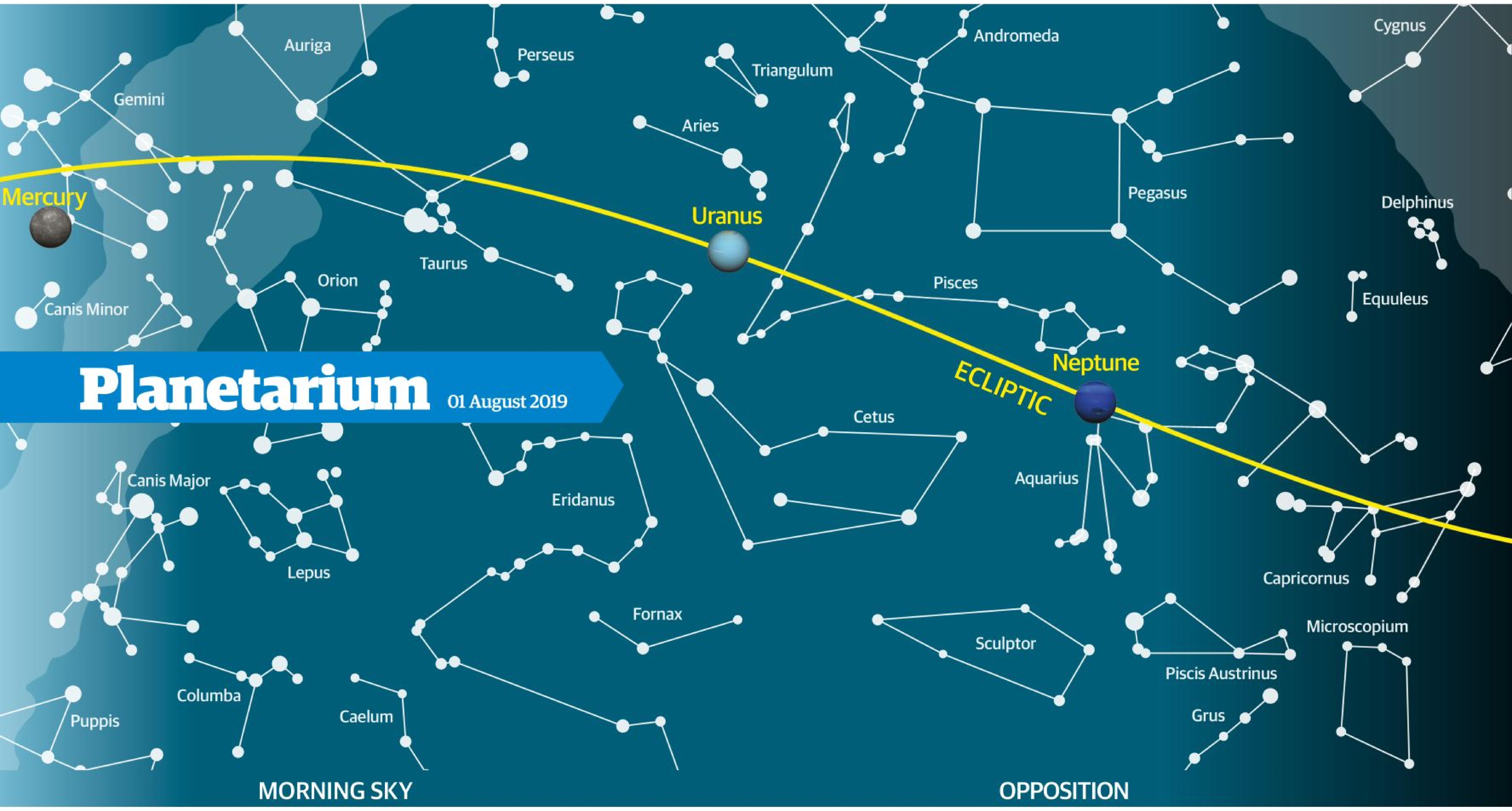
14 AUG

The globular cluster Messier 15 is well placed for observation in Pegasus

- Naked eye
- Binoculars
- Small telescope
- Medium telescope
- Large telescope

Planetarium

01 August 2019



Moon calendar

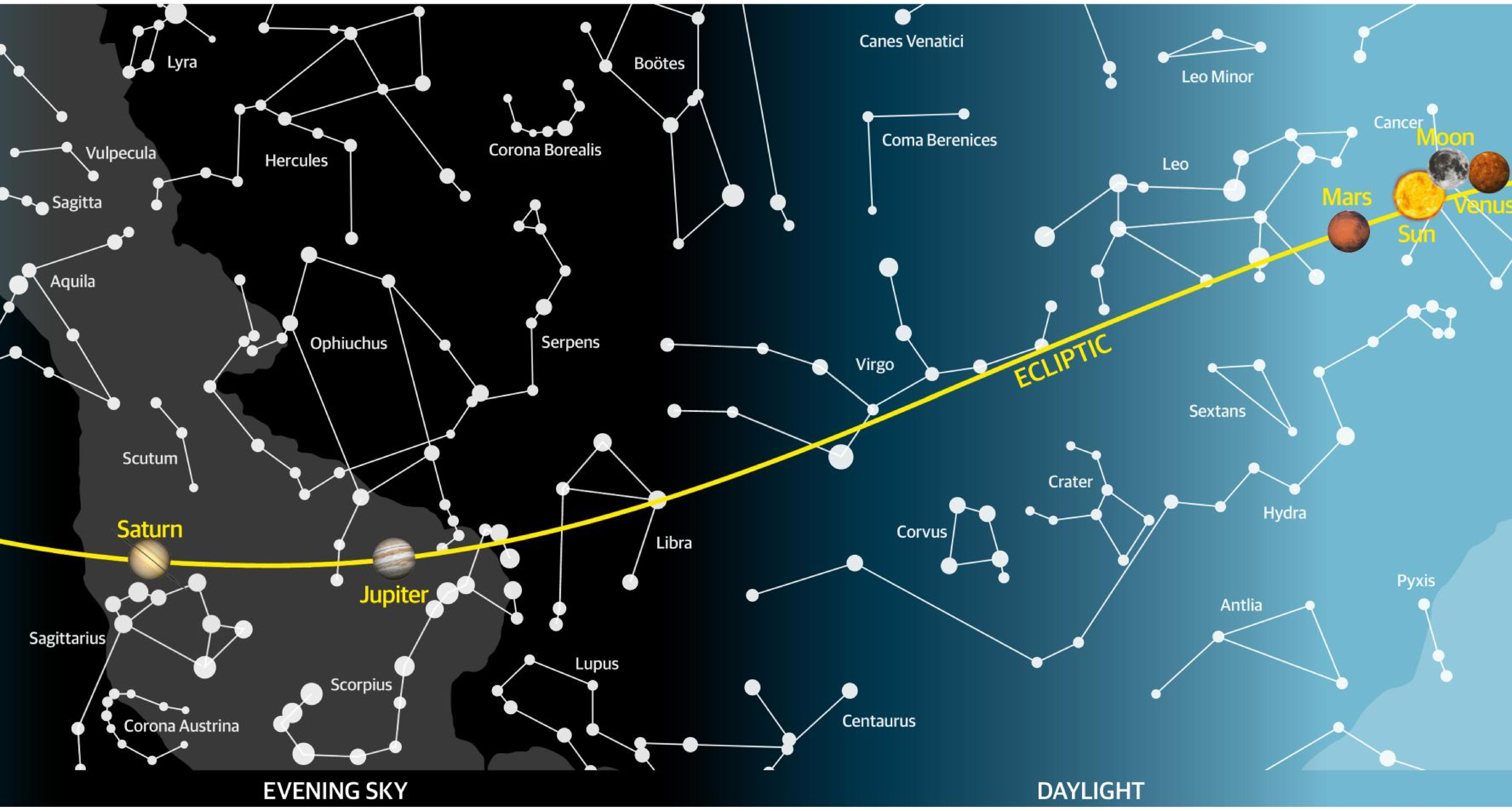
* The Moon does not pass the meridian on 14 August

			18 JUL 98.7% ◒06:22 ◓22:17	19 JUL 95.6% ◒07:27 ◓22:43	20 JUL 90.7% ◓08:33 ◒23:04	21 JUL 84.3% ◓09:38 ◒23:24
22 JUL 76.6% ◓10:44 ◒23:42	23 JUL 67.8% ◓11:50 ◒23:59	24 JUL 58.2% ◓12:56 ◒--:--	25 JUL TQ 48.2% ◓00:18 ◒14:05	26 JUL 37.9% ◓00:39 ◒15:15	27 JUL 27.7% ◓01:03 ◒16:28	28 JUL 18.3% ◓01:34 ◒17:40
29 JUL 10.2% ◓02:13 ◒18:49	30 JUL 4.1% ◓03:04 ◒19:51	31 JUL 0.7% ◓04:09 ◒20:42	1 AUG NM 0.3% ◓05:25 ◒21:23	2 AUG 3.2% ◓06:49 ◒21:56	3 AUG 9.1% ◓08:14 ◒22:23	4 AUG 17.5% ◓09:39 ◒22:47
5 AUG 27.7% ◒11:01 ◓23:09	6 AUG 38.9% ◒12:21 ◓23:31	7 AUG FQ 50.3% ◒13:39 ◓23:55	8 AUG 61.4% ◒14:55 ◓--:--	9 AUG 71.6% ◒00:22 ◓16:07	10 AUG 80.6% ◒00:54 ◓17:14	11 AUG 88.1% ◒01:33 ◓18:13
12 AUG 93.9% ◒02:19 ◓19:04	13 AUG 97.8% ◒03:13 ◓19:45	14 AUG --:--% ◒04:13 ◓20:19	15 AUG FM 99.7% ◒05:17 ◓21:29			

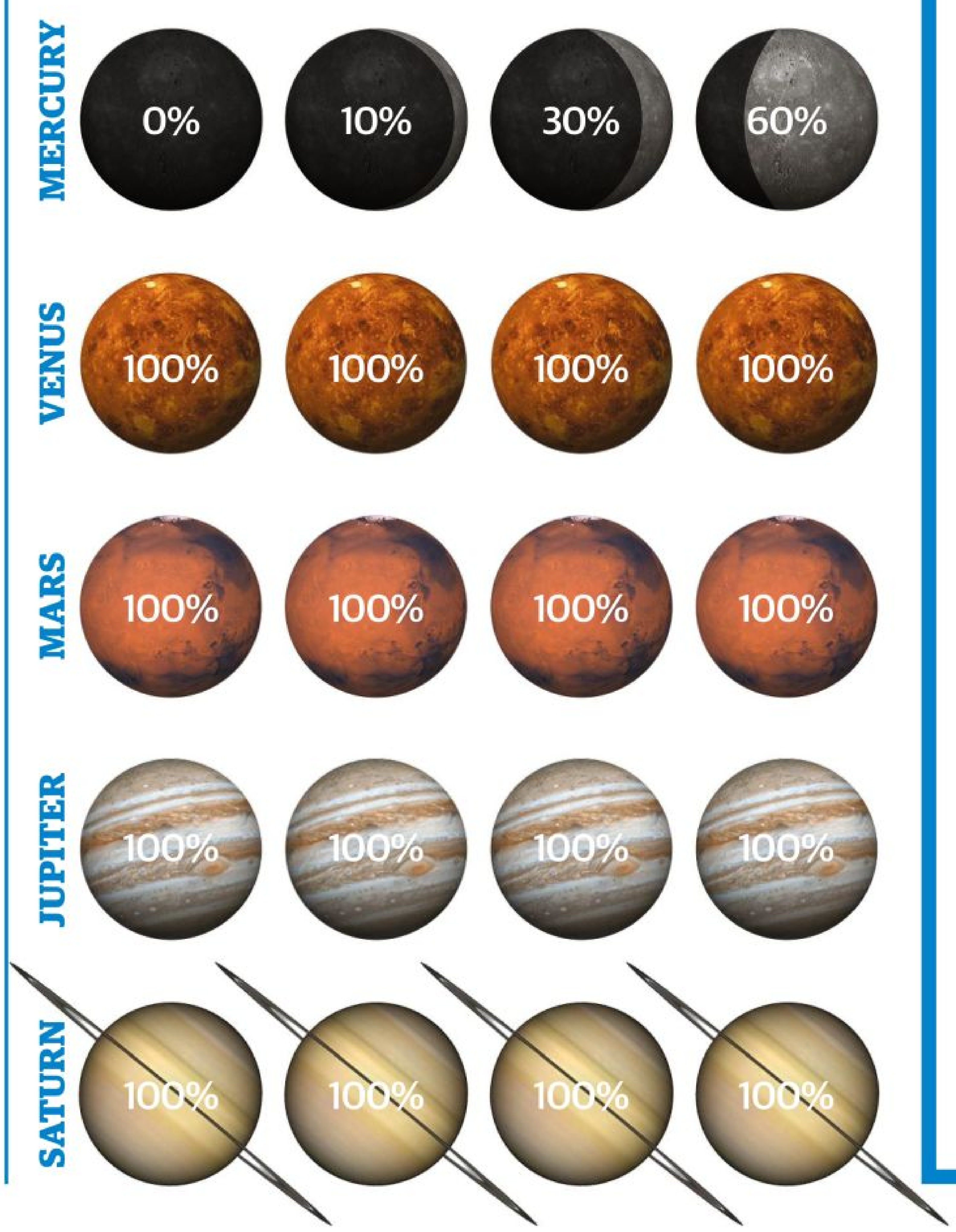
% Illumination
◓ Moonrise time
◒ Moonset time

FM Full Moon
NM New Moon
FQ First quarter
LQ Last quarter

All figures are given for 00h at midnight (local times for London, UK)



Illumination percentage



	25 JUL	1 AUG	8 AUG	15 AUG
MERCURY	0%	10%	30%	60%
VENUS	100%	100%	100%	100%
MARS	100%	100%	100%	100%
JUPITER	100%	100%	100%	100%
SATURN	100%	100%	100%	100%

Planet positions

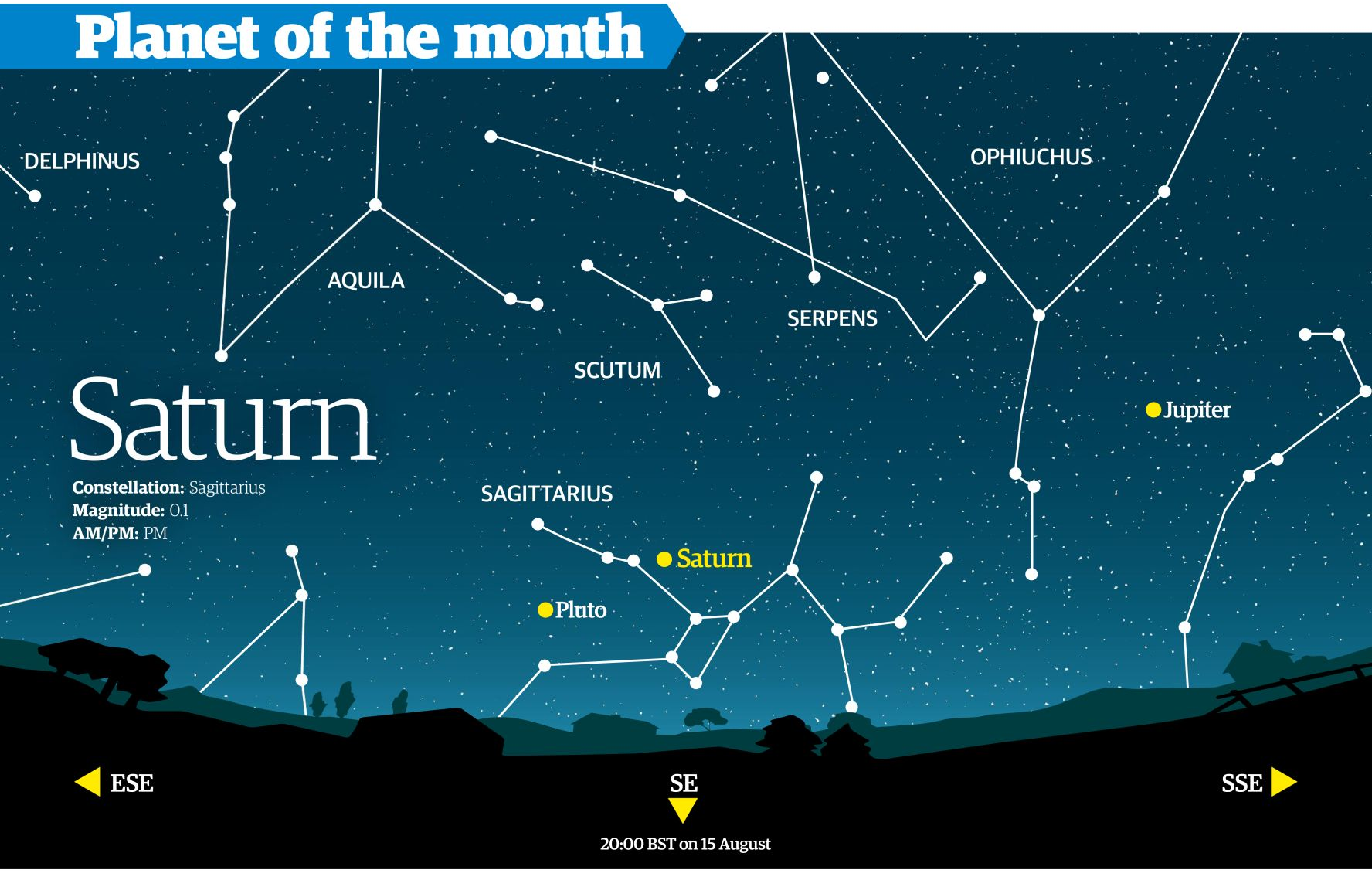
All rise and set times are given in BST

	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	18 Jul	08h 06m 56s	+15° 25' 17"	Cancer	4.7	06:08	20:58
	25 Jul	07h 48m 05s	+16° 10' 16"	Gemini	4.6	05:17	20:16
	01 Aug	07h 39m 29s	+17° 40' 34"	Gemini	2.0	04:32	19:49
	08 Aug	07h 51m 08s	+19° 00' 43"	Gemini	0.3	04:08	19:41
	15 Aug	08h 24m 17s	+19° 10' 04"	Cancer	-0.7	04:12	19:48
VENUS	18 Jul	07h 15m 29s	+22° 47' 52"	Gemini	-3.9	04:29	20:53
	25 Jul	07h 52m 22s	+21° 40' 53"	Gemini	-3.9	04:46	20:55
	01 Aug	08h 28m 37s	+20° 02' 56"	Cancer	-3.9	05:06	20:53
	08 Aug	09h 04m 03s	+17° 56' 52"	Cancer	-3.9	05:27	20:47
	15 Aug	09h 38m 36s	+15° 26' 09"	Leo	-3.9	05:49	20:39
MARS	18 Jul	08h 50m 47s	+18° 53' 15"	Cancer	1.8	06:30	22:02
	25 Jul	09h 08m 44s	+17° 37' 58"	Cancer	1.8	06:29	21:45
	01 Aug	09h 26m 26s	+16° 16' 58"	Leo	1.8	06:27	21:27
	08 Aug	09h 43m 53s	+14° 50' 47"	Leo	1.8	06:25	21:09
	15 Aug	10h 01m 06s	+13° 19' 58"	Cancer	1.8	06:23	20:50
JUPITER	18 Jul	16h 55m 45s	-22° 07' 50"	Ophiuchus	-2.5	18:18	02:26
	25 Jul	16h 53m 51s	-22° 06' 12"	Ophiuchus	-2.4	17:20	01:28
	01 Aug	16h 52m 33s	-22° 05' 27"	Ophiuchus	-2.6	19:19	03:26
	08 Aug	16h 51m 52s	-22° 05' 43"	Ophiuchus	-2.4	16:52	01:00
	15 Aug	16h 51m 51s	-22° 07' 01"	Ophiuchus	-2.4	16:24	00:32
SATURN	18 Jul	19h 10m 42s	-22° 08' 04"	Sagittarius	0.1	20:33	04:40
	25 Jul	19h 08m 34s	-22° 12' 16"	Sagittarius	0.1	20:04	04:10
	01 Aug	19h 06m 33s	-22° 16' 12"	Sagittarius	0.1	19:35	03:40
	08 Aug	19h 04m 42s	-22° 19' 48"	Sagittarius	0.1	19:06	03:10
	15 Aug	19h 03m 04s	-22° 23' 02"	Sagittarius	0.1	18:37	02:41

This month's planets

Saturn takes the spotlight, while Mercury, Venus and Mars are challenging targets because of their proximity to the Sun

Planet of the month



Saturn

Constellation: Sagittarius
Magnitude: 0.1
AM/PM: PM

20:00 BST on 15 August

Saturn – known as the 'Ringed Planet' because of its system of gorgeous, bright rings – is visible low in the southeast as soon as the sky begins to darken after sunset. You'll notice immediately how Saturn is much fainter and a warmer, more golden colour than Jupiter, which will be blazing some distance over to its right and slightly higher in the sky, but at magnitude 0.1 it will still be obvious to your naked eye. Unfortunately Saturn will not reach any great altitude this month, and will always be so low down in the south that if you have any trees, hills or tall buildings in that direction they may hide it from your view; to see Saturn you might have to leave your favourite observing spot and find somewhere with an unobstructed view.

Saturn moves very slowly across the sky, lingering within the borders of one constellation all year, and through this summer it will be shining in Sagittarius, to the upper left of the handle of the famous 'Teapot' asterism. Again this will be very low in the sky through summer, and its stars are quite faint, so don't be too disappointed if you can't see them.

Saturn will set in the southwest as the sky starts to brighten in the northeast with the approach of dawn. While it is in the sky you should definitely train your binoculars on it because they will be powerful enough to show you its largest moon, Titan, shining close to the planet, looking like a tiny but obvious 'star' near the distant world itself.

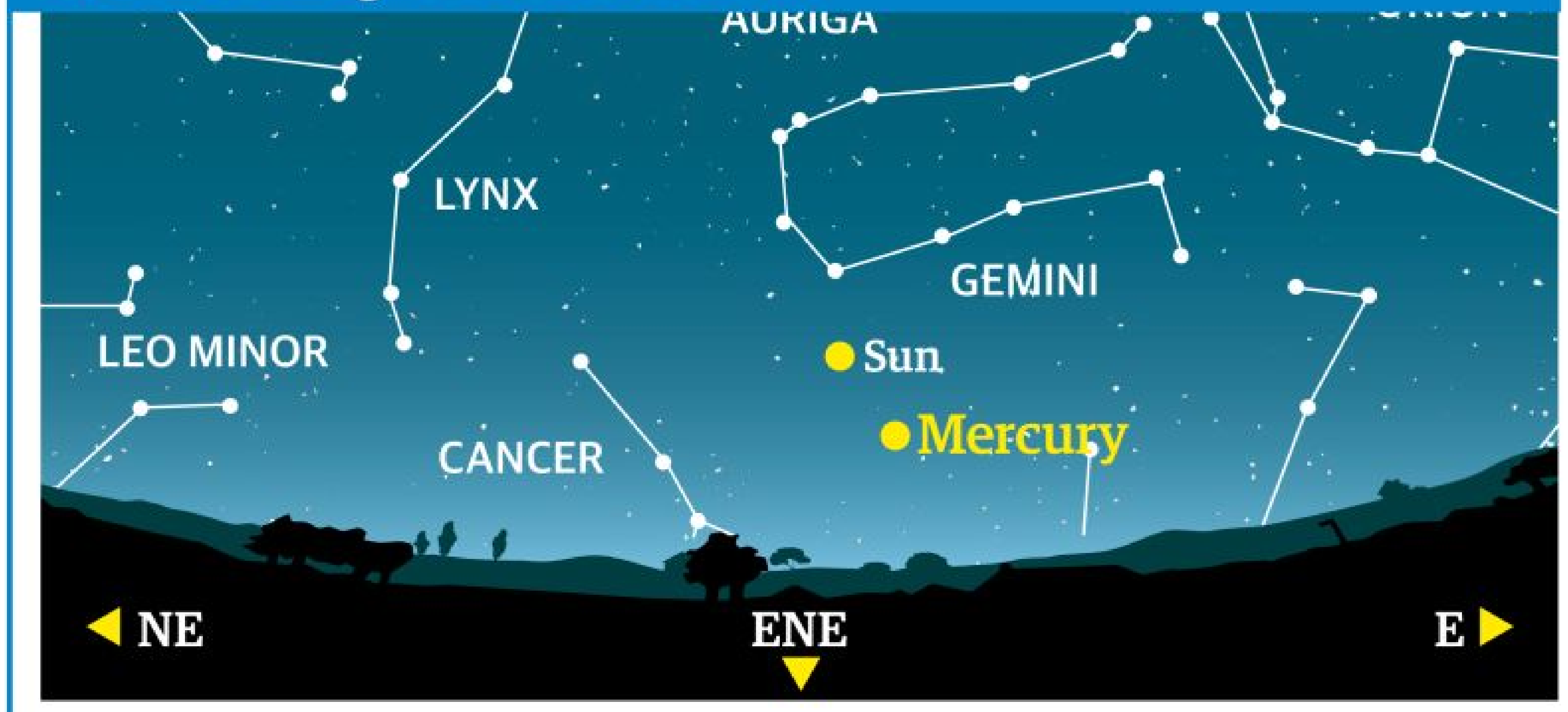
Saturn will have several 'close encounters' with the Moon during our observing period. Look for it on the morning of 18 July and you'll see the Moon some 20 degrees to its left, and in mid-August Saturn and the Moon will be much closer on the mornings of 12 and 13 August when they'll be a mere six degrees or so apart on each occasion.

If you want to see Saturn's famous rings, you'll need a telescope. A pair of really powerful binoculars might resolve them, but you'll need the higher magnification a small telescope provides to really separate the rings from Saturn itself.

> "Saturn is much fainter and a warmer, more golden colour than Jupiter"

This month's planets

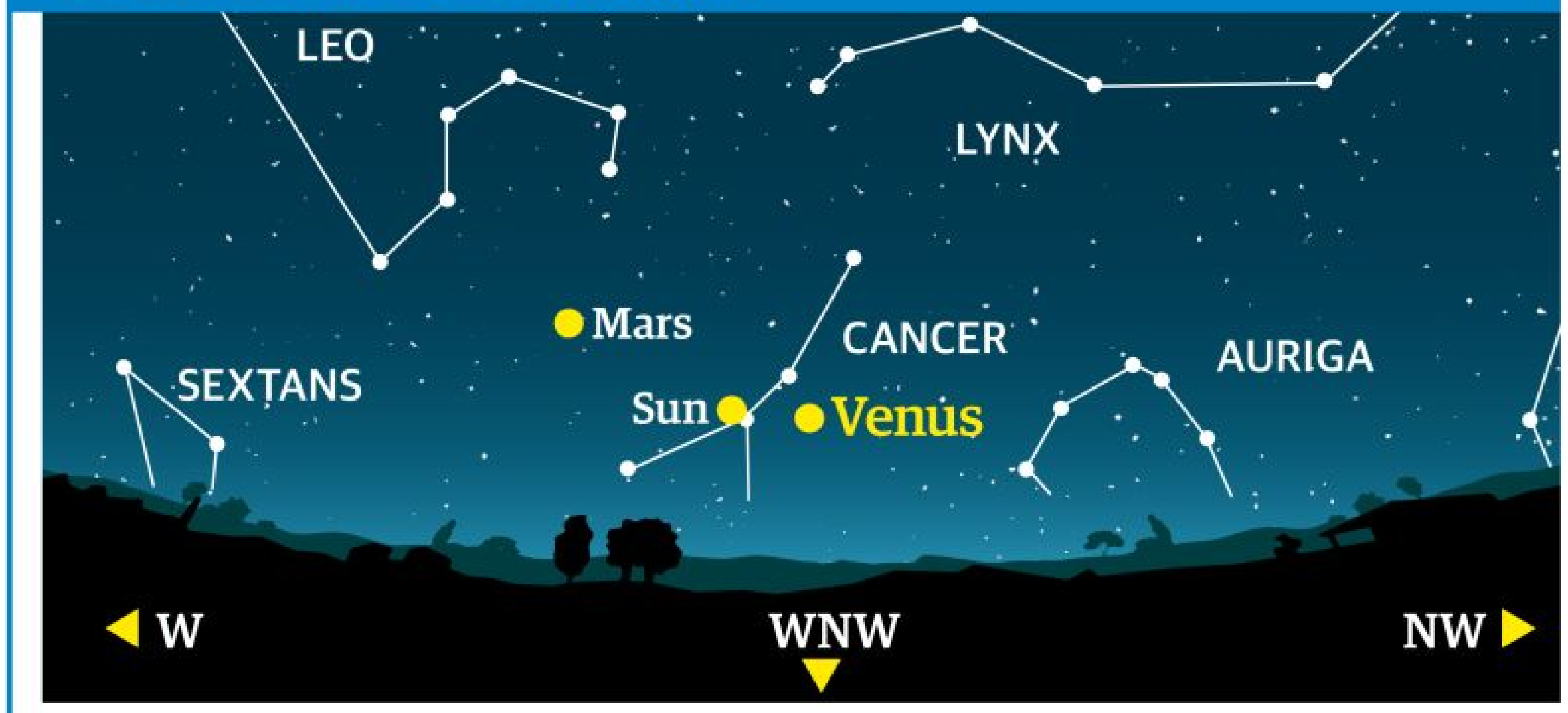
Mercury 06:30 BST on 20 July



Constellation: Gemini
Magnitude: 0.4
AM/PM: AM

If you want to see this roughly Moon-sized planet you'll have to wait until it has slid past the Sun and climbed up into the morning sky, and that will happen at the start of August. Mercury will be visible low in the northeast as a faint, copper-hued star in the dawn glow. Mercury will be at its best around 12 to 13 August.

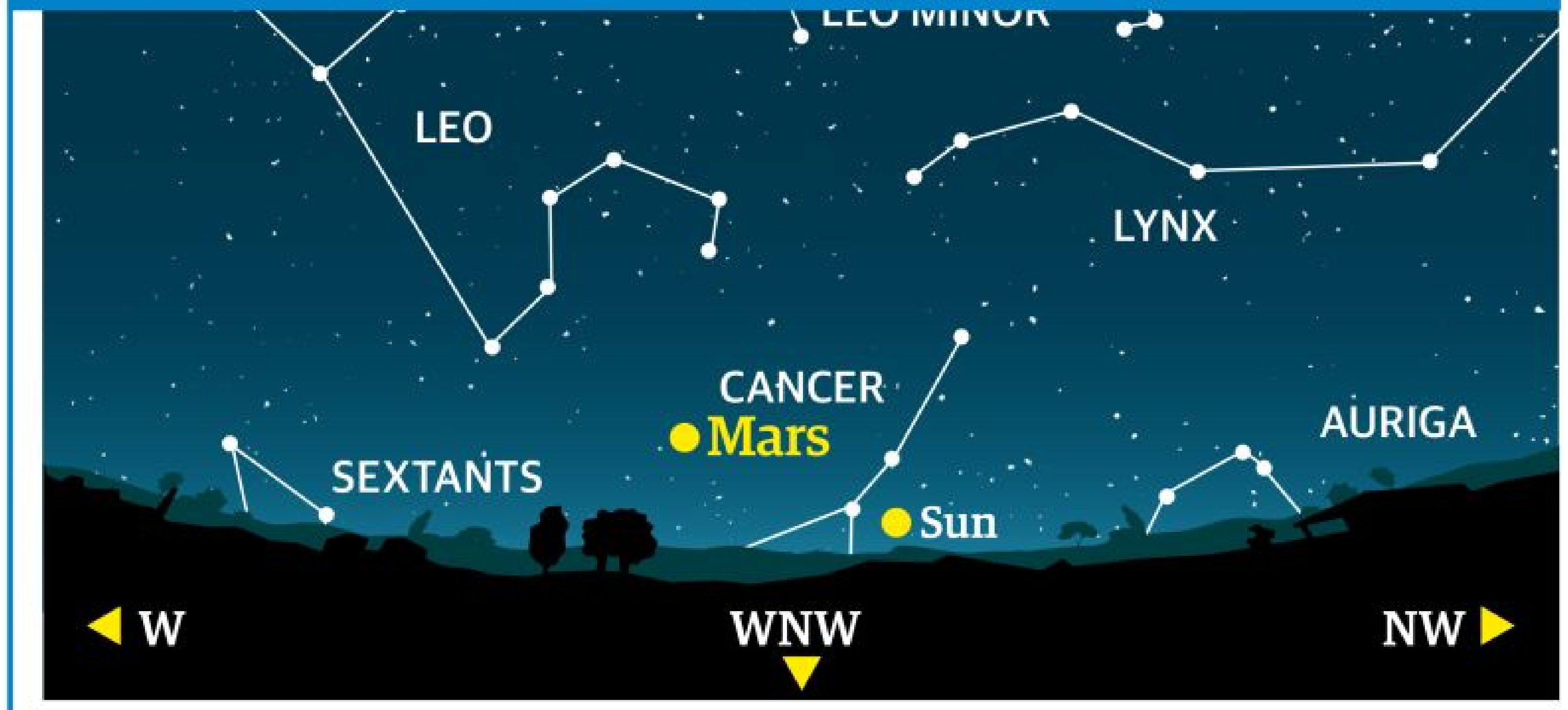
Venus 20:23 BST on 1 August



Constellation: Gemini
Magnitude: -3.9
AM/PM: PM

At the start of our observing period Venus is low in the northeast before sunrise, but only for a very short time. As the days pass, it will move closer to the Sun until it is just too close to it to be visible. But don't despair too much – Venus will be back in the sky soon, and by Christmas will be very bright and easy to see.

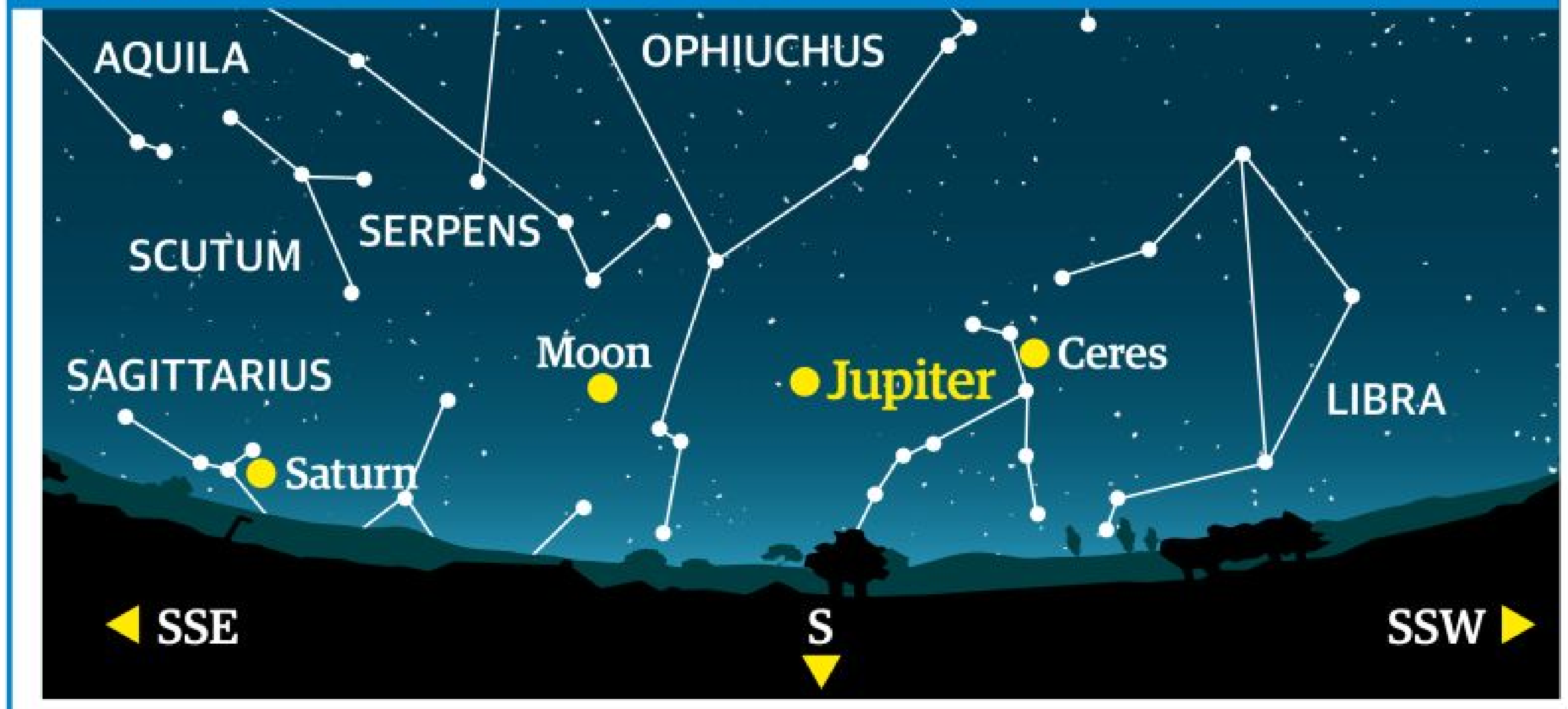
Mars 20:30 BST on 30 July



Constellation: Cancer
Magnitude: 1.8
AM/PM: PM

In mid-July it will be an evening object, but very low in the northwest after sunset and so hard to see in the bright twilight sky, especially with that faint magnitude of 1.8 which will make it barely as bright as the stars of the Big Dipper. As July drifts into August Mars will move towards the Sun, eventually too close to be seen.

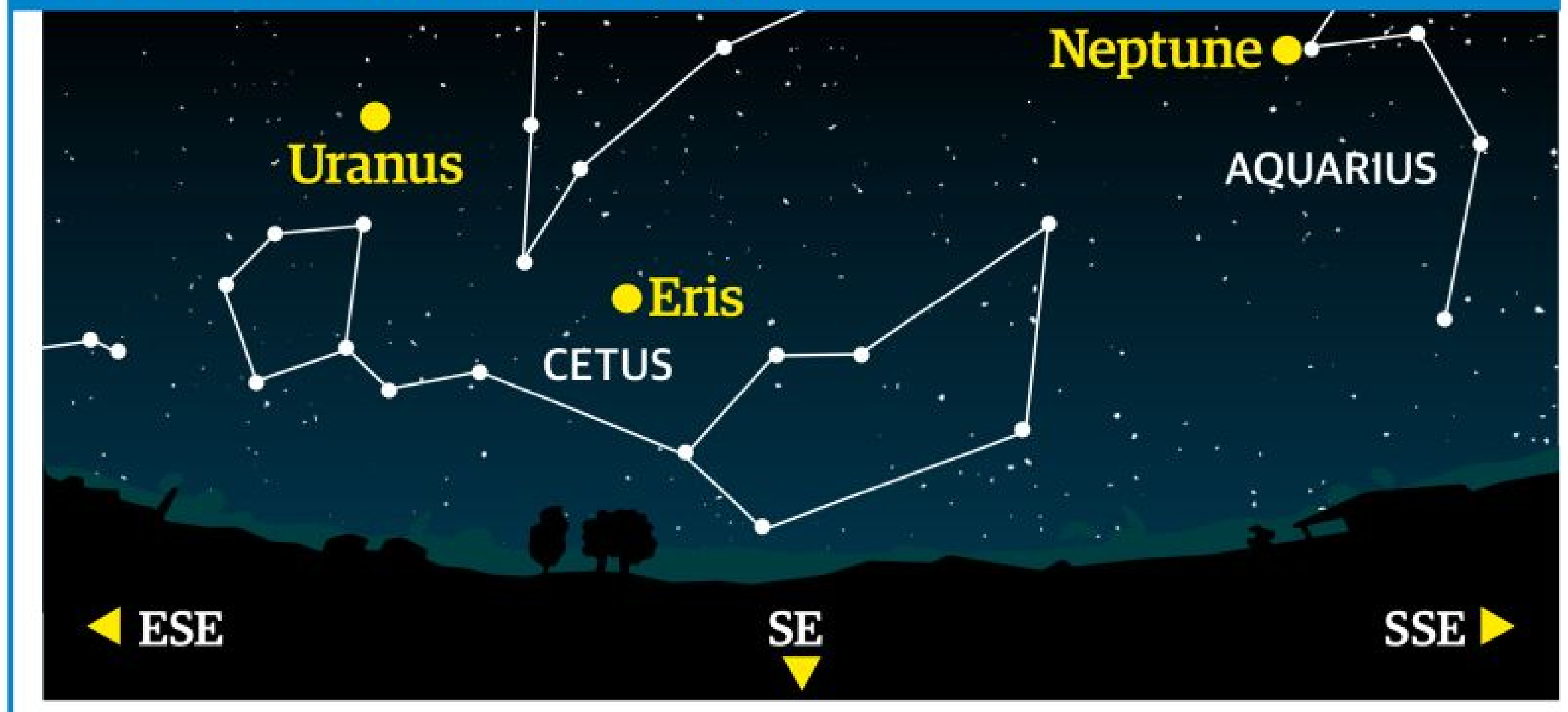
Jupiter 20:30 BST on 10 August



Constellation: Ophiuchus
Magnitude: -2.5
AM/PM: PM

Jupiter will already be shining high in the southeast after sunset. All through the month ahead Jupiter will be in the sky until the early hours, tracing out a low, lazy arc above the southern horizon before setting around 01:00. Look for the waning gibbous Moon just two degrees away from Jupiter on the evening of 9 August.

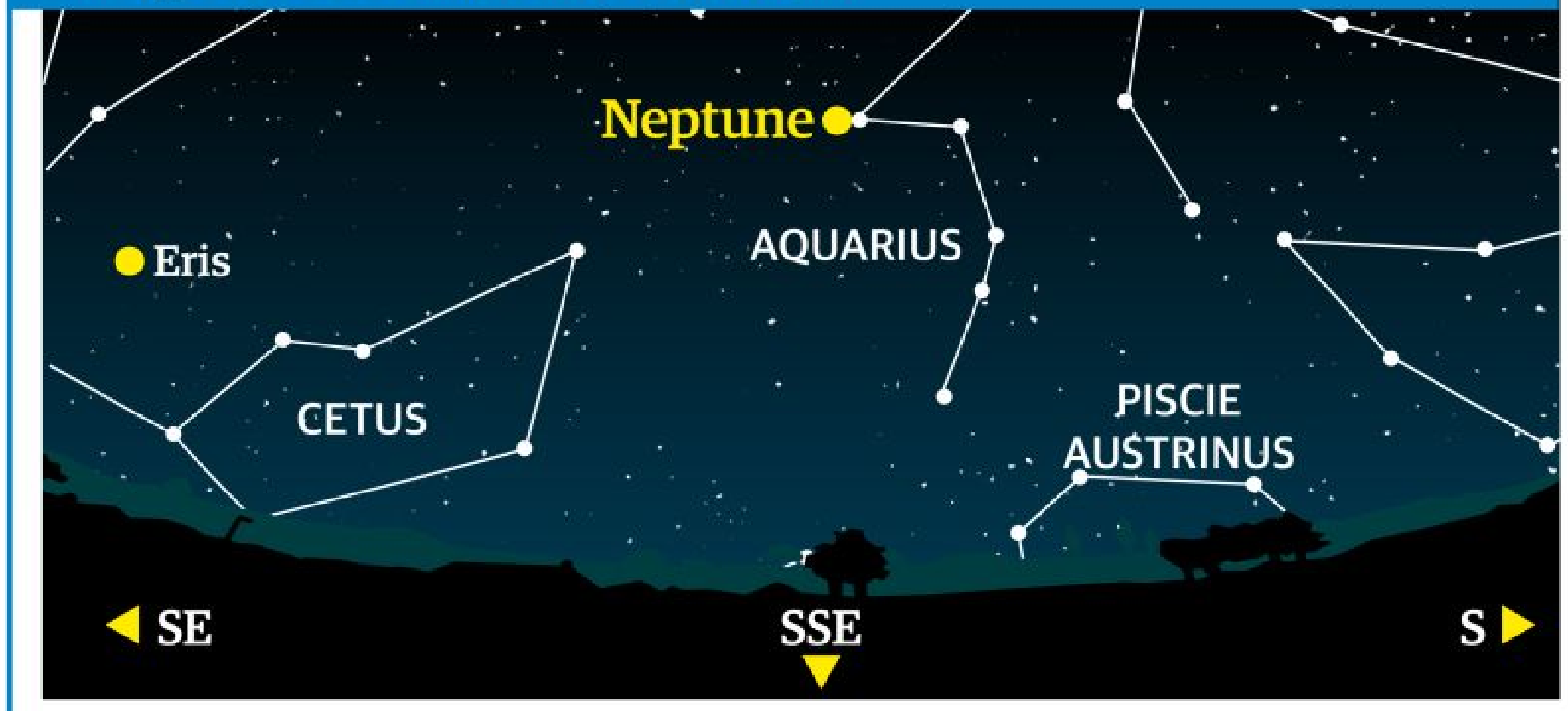
Uranus 02:00 BST on 13 August



Constellation: Aries
Magnitude: 5.8
AM/PM: AM

As mighty Jupiter is setting in the west, distant Uranus will be rising in the east. At magnitude 5.8 this faraway green world is technically a naked-eye object, but you'd have to know the night sky like the back of your hand to pick it out from the many thousands of stars behind it that are the same brightness.

Neptune 02:00 BST on 11 August



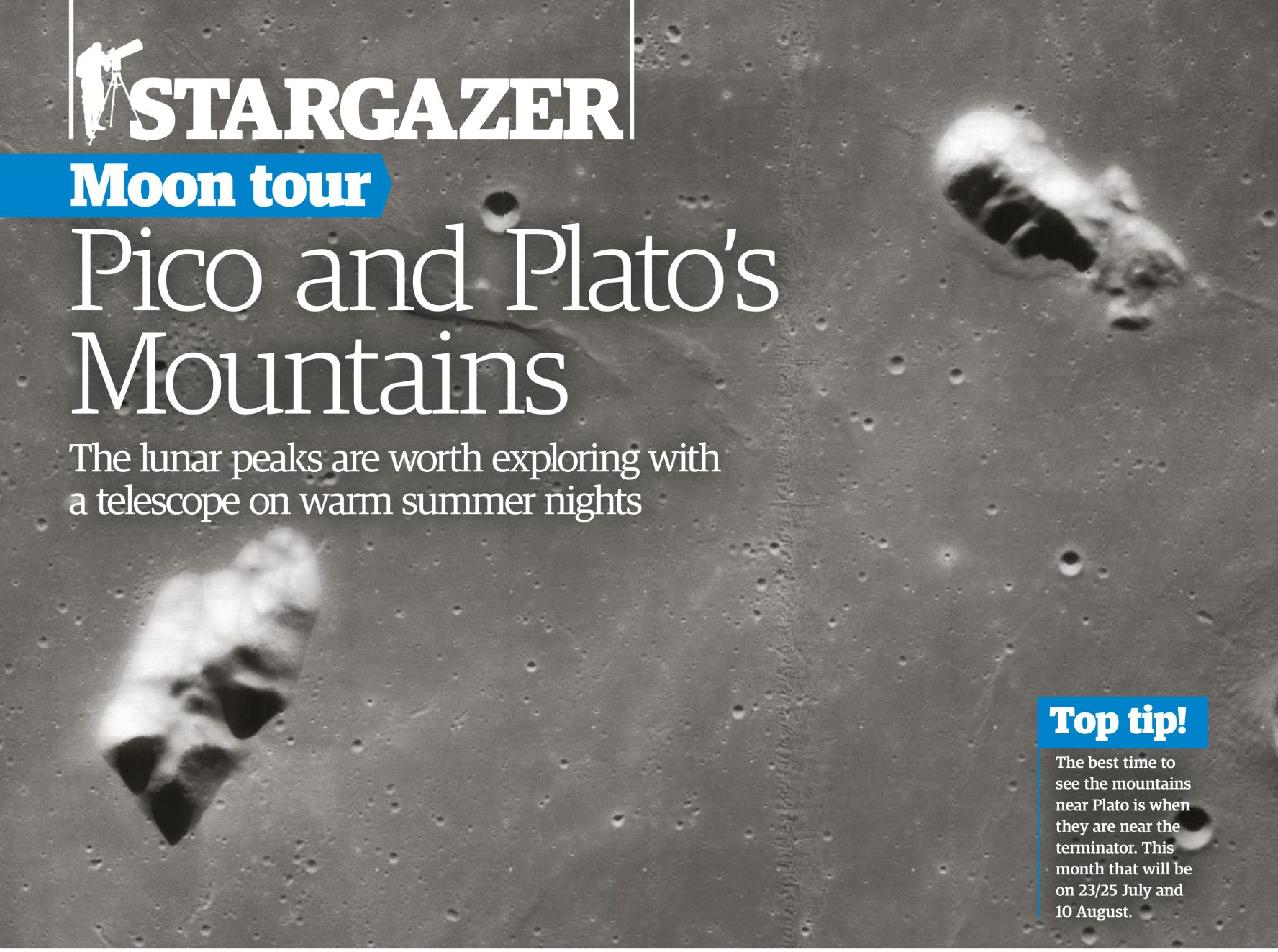
Constellation: Aquarius
Magnitude: 7.8
AM/PM: AM

Neptune rises around midnight throughout our observing window, but at magnitude 7.8 you will definitely need a good pair of binoculars to find it in the sky. On 21 July lonely, faraway Neptune will be seven degrees above and to the left of the Moon, which might help you identify it.

Moon tour

Pico and Plato's Mountains

The lunar peaks are worth exploring with a telescope on warm summer nights



Top tip!

The best time to see the mountains near Plato is when they are near the terminator. This month that will be on 23/25 July and 10 August.

Summer is a great time to enjoy looking at the Moon. For one thing it doesn't climb very high in the sky, so you don't have to get a crick in your neck staring up at it. Also, the long, warm nights are perfect for Moon-gazing.

If you have a pair of binoculars you can see a surprising amount of detail on the Moon. They will show you its largest craters – huge holes blown out of its surface by the impact of asteroids millions or even billions of years ago. They will also show you its highest mountain ranges, some of which rival Earth's most beautiful. But the most striking sights in binoculars are the Moon's seas, or 'mare', which are not bodies of water but huge, flat plains of ancient lava which flowed out of the Moon like the yolk of an egg and spread across its surface before freezing in the aftermath of enormous asteroid impacts which set the Moon ringing like a cosmic church bell.

One of the largest seas is Mare Imbrium, which forms the bloated right eye of 'the Man in the Moon' when the Moon is full. It's top and centre on the disc. Looking at it through binoculars you will see a small, dark circle or oval at the top of Mare Imbrium. This is a walled plain called 'Plato', and it's one of the most famous features on the Moon. But if you have a telescope there is something worth looking at just to the south of Plato, something that you'll want to look at with the highest magnification your telescope can manage.

When Plato is close to the terminator this month focus your telescope on it, put in a high-power eyepiece and look just to its south. There you'll see what looks like a chain of some small rugged 'islands' out in the dark sea, close to the northern shore of Mare Imbrium. These nubs and stubs of rock are actually mountains, sticking up out of the lava plain of Mare Imbrium like pieces of bone or fossils exposed by the digging and brushing of patient archaeologists. You'll see them running from west to east in your eyepiece in a ragged chain. The more westerly ones are the Montes Teneriffe, the Teneriffe Mountains, and were named after the island of Tenerife in the Canaries.

> "If you have a telescope there is something worth looking at just to the south of Plato"

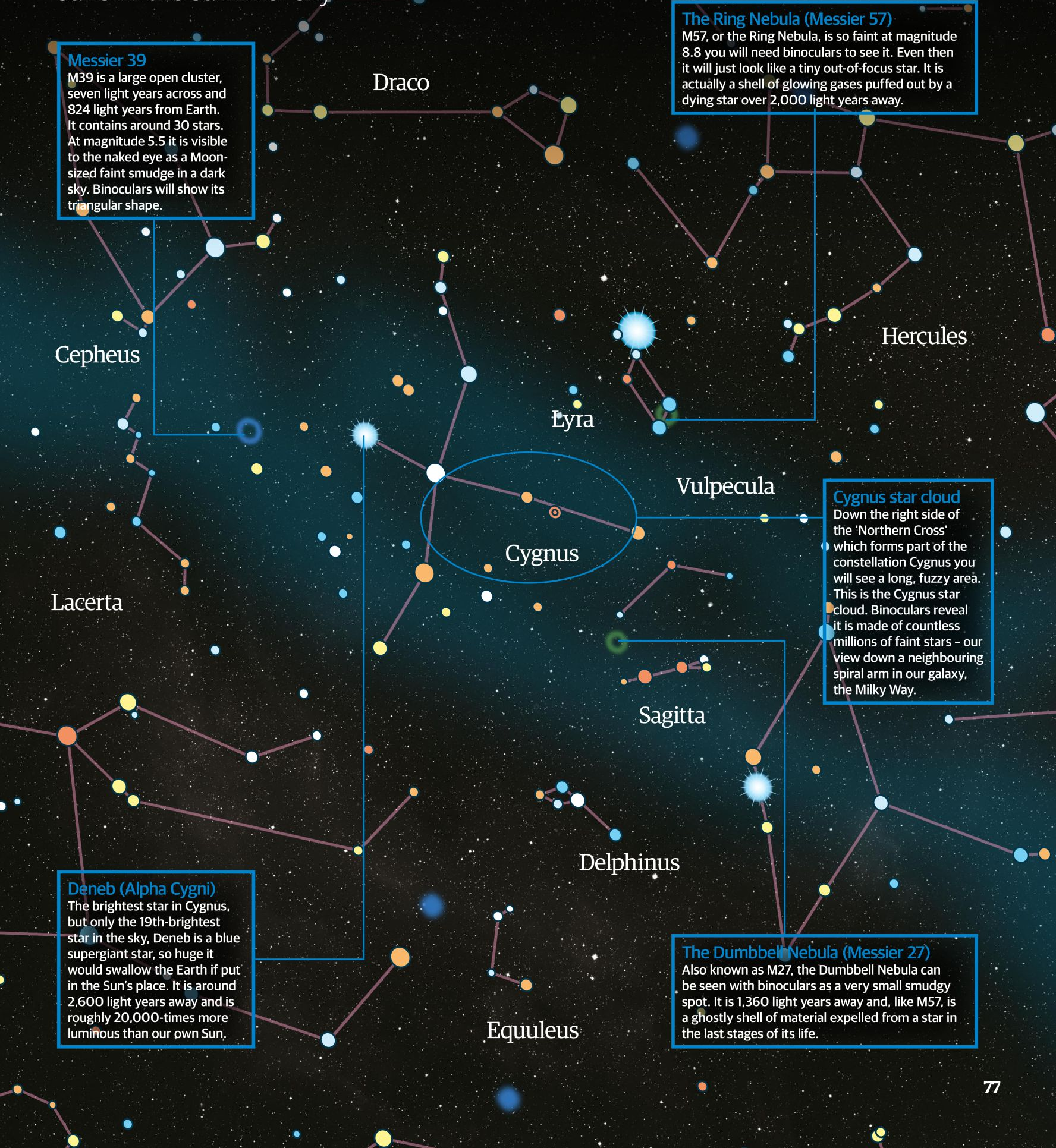
Look a little further east and just to the south and you'll see a mountain sticking up out of the lava plain all on its own. This is Mons Pico, named after the volcano in the centre of Pico Island in the Azores. That volcano rises up 2.3 kilometres (1.4 miles) from the ocean, and the peak of its lunar namesake is 2.4 kilometres (1.5 miles) above Mare Imbrium, making it just a little higher.

Mons Pico is by no means the tallest or most impressive peak on the Moon, but it is one of the most striking. When the terminator – the line between night and day – is either approaching it or has just swept over it, Mons Pico can cast a long, very dark, very obvious shadow across Mare Imbrium which really makes it stand out. For this reason it's a firm favourite of many lunar observers.

When can you see this peak this month? At the start of our observing period it is bathed in full sunlight because the Moon will be just past full, but it will just look like a flat, white blob in your telescope. Look again around 23 July and by then Mons Pico will be casting a shadow as the Sun begins to set in its sky. By 25 July Pico will be on the terminator and will vanish from view, not to return until around 10 August when the Sun will rise in its sky again and it will stand out starkly on the Moon once more, casting a long, ink-black shadow across the lava plain it stands in.

Naked eye & binocular targets

See a cloud of stars and shells of gas produced by faraway dying suns in the summer sky



Messier 39

M39 is a large open cluster, seven light years across and 824 light years from Earth. It contains around 30 stars. At magnitude 5.5 it is visible to the naked eye as a Moon-sized faint smudge in a dark sky. Binoculars will show its triangular shape.

The Ring Nebula (Messier 57)

M57, or the Ring Nebula, is so faint at magnitude 8.8 you will need binoculars to see it. Even then it will just look like a tiny out-of-focus star. It is actually a shell of glowing gases puffed out by a dying star over 2,000 light years away.

Cygnus star cloud

Down the right side of the 'Northern Cross' which forms part of the constellation Cygnus you will see a long, fuzzy area. This is the Cygnus star cloud. Binoculars reveal it is made of countless millions of faint stars – our view down a neighbouring spiral arm in our galaxy, the Milky Way.

Deneb (Alpha Cygni)

The brightest star in Cygnus, but only the 19th-brightest star in the sky, Deneb is a blue supergiant star, so huge it would swallow the Earth if put in the Sun's place. It is around 2,600 light years away and is roughly 20,000-times more luminous than our own Sun.

The Dumbbell Nebula (Messier 27)

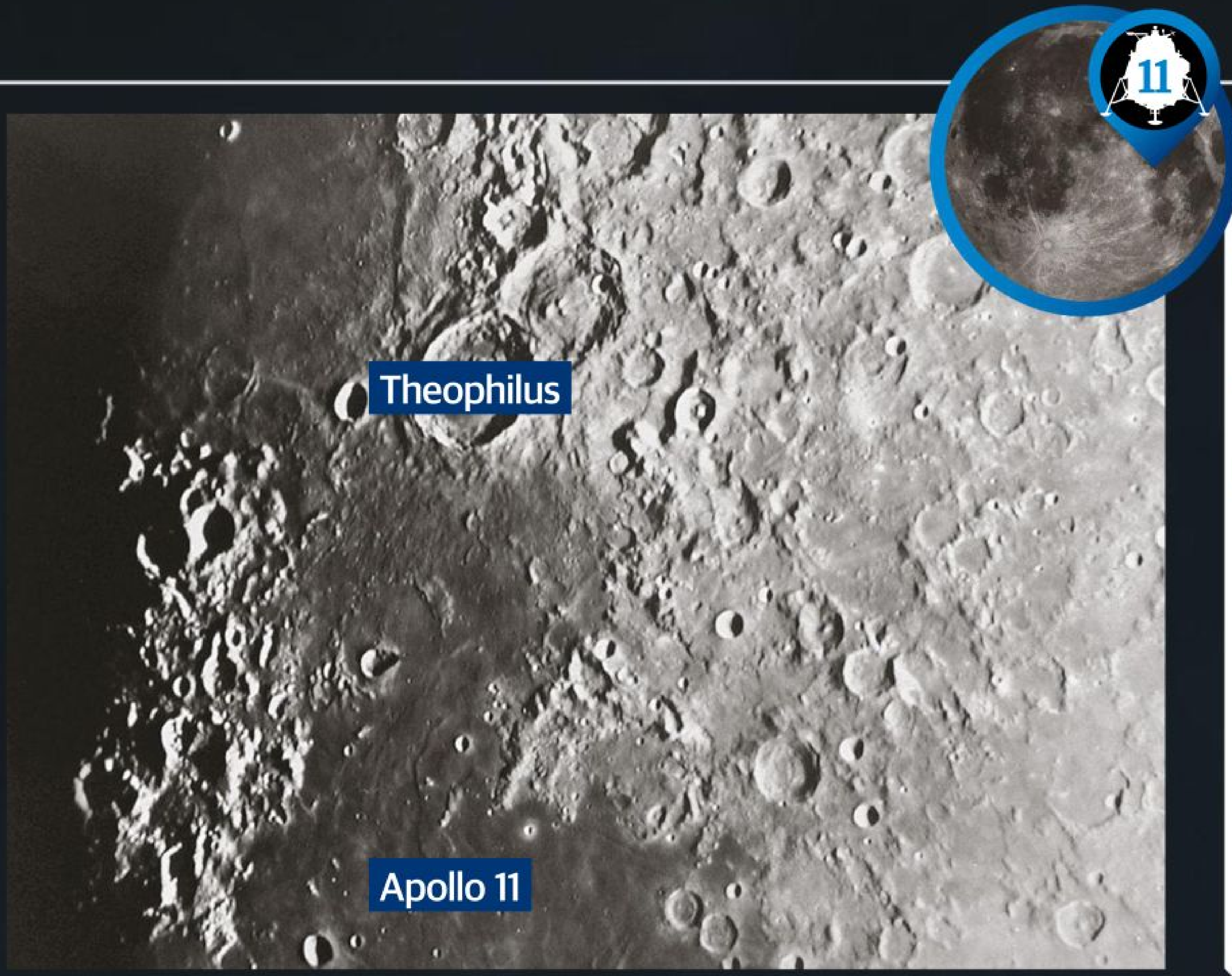
Also known as M27, the Dumbbell Nebula can be seen with binoculars as a very small smudgy spot. It is 1,360 light years away and, like M57, is a ghostly shell of material expelled from a star in the last stages of its life.

OBSERVE THE APOLLO LANDING SITES TONIGHT!

Turn your telescope, binoculars or unaided eye to the Moon and you'll see where man, rovers and landers stepped onto another world

Today there is a lot of excited talk about going to the Moon again. Shining brightly in our sky, it calls to us like a celestial siren, just as it always has done. NASA is still debating whether they should send astronauts straight to Mars, bypassing the Moon altogether, or only go to Mars after a number of successful precursor missions to Earth's natural satellite. Meanwhile, the European Space Agency is looking to the Moon as the potential site of a scientific outpost where different nations could work together in a 'lunar village', much like international scientists now work in Antarctica. Private companies are also planning to mine the Moon for resources, and there's even a competition to land robot rovers on the Moon and have them send live video back to Earth.

With all this going on it's important to remember we've already been to the Moon. True, it happened a long, long time ago – so long ago that children today learn about it in school history classes, just as they learn about the Egyptians, Vikings or the Roman Empire – but the Apollo missions were a spectacular success and represented a golden age of exploration.



Apollo 11

Minimum optical aid:
Telescope with magnification of 50x or more

Where on the Moon:
Sea of Tranquillity

Best phase to observe:
Between first quarter and full

Finding Apollo 11's landing site is quite easy. Just find the large crater Theophilus and put it at the top of your field of view. You'll see an obvious promontory of bright ground beneath the crater, jutting out into the darker lava sea – Tranquillity Base is just beneath this striking feature.

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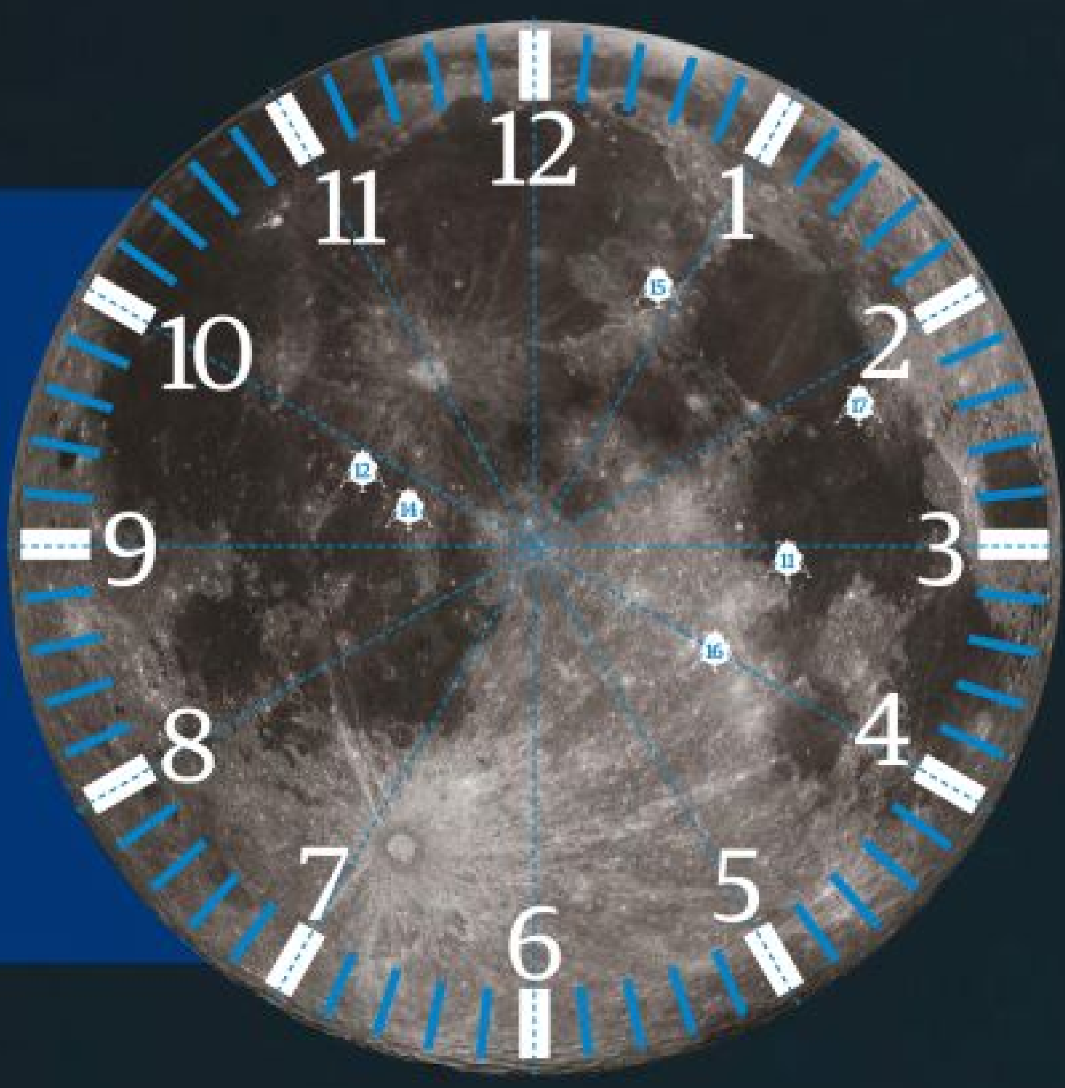
Using the Moon as a clock face

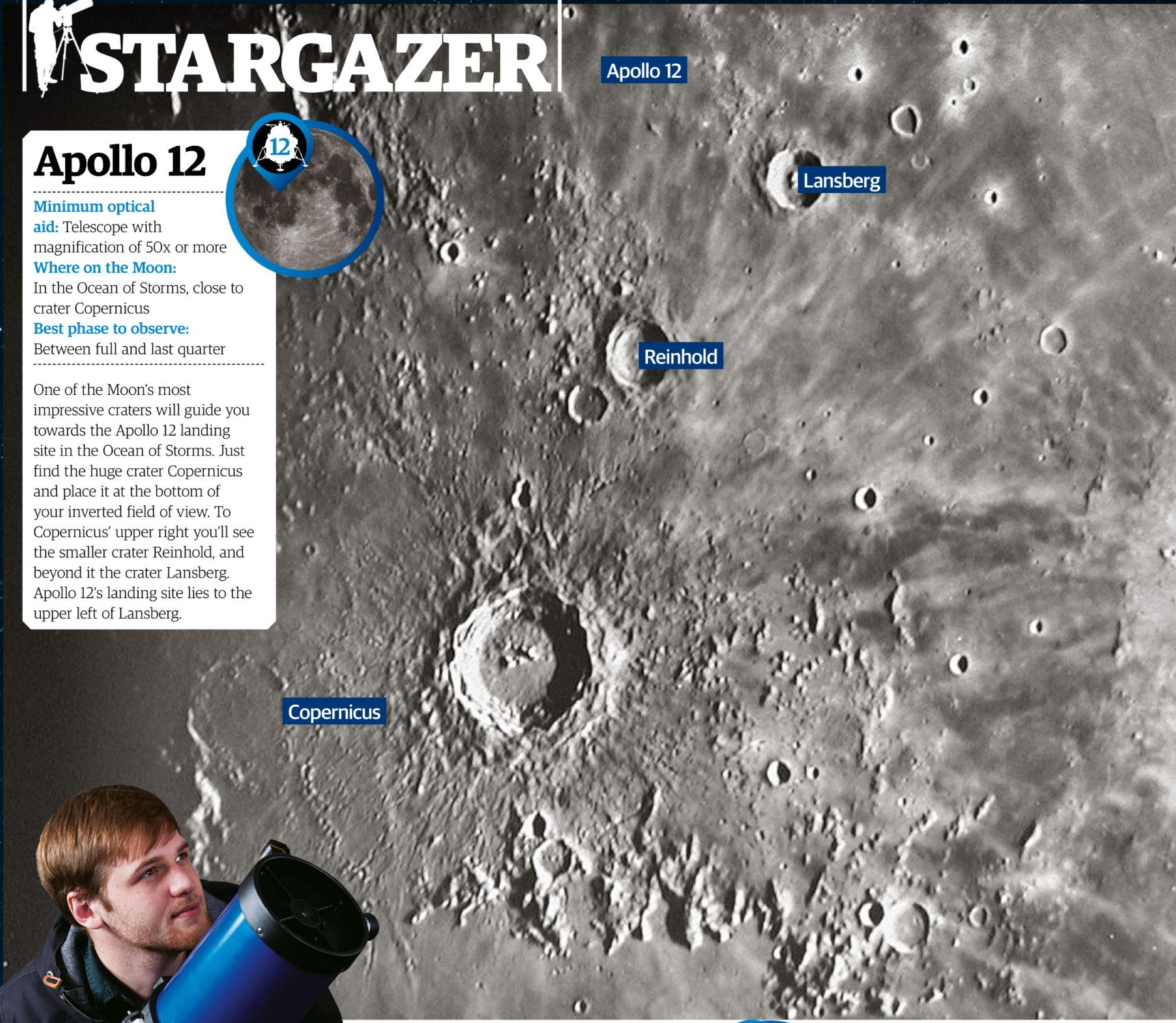
Locate the rough locations of the Apollo landing sites using this quick trick

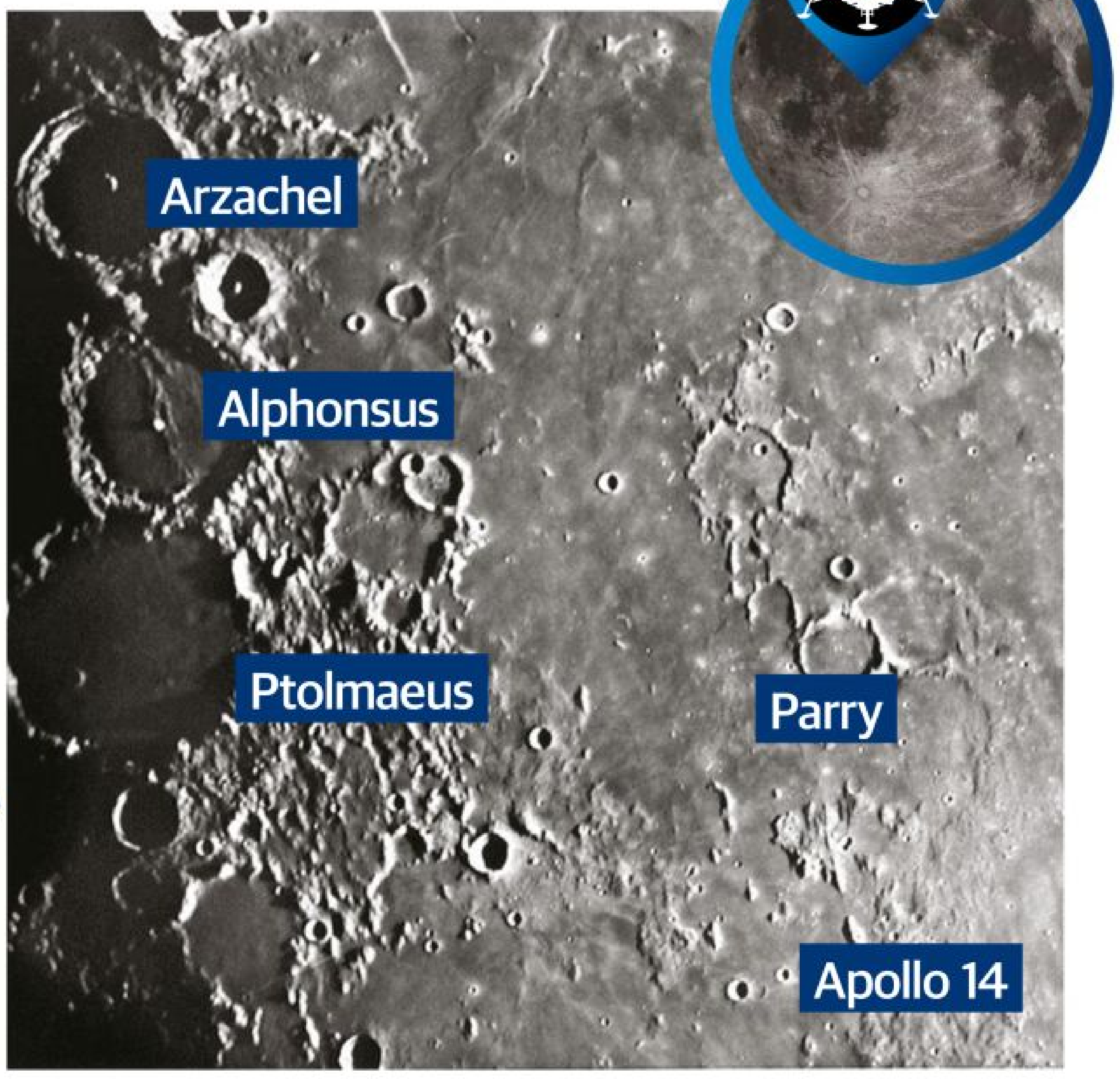


Apollo 12

Minimum optical aid: Telescope with magnification of 50x or more
Where on the Moon: In the Ocean of Storms, close to crater Copernicus
Best phase to observe: Between full and last quarter

One of the Moon's most impressive craters will guide you towards the Apollo 12 landing site in the Ocean of Storms. Just find the huge crater Copernicus and place it at the bottom of your inverted field of view. To Copernicus' upper right you'll see the smaller crater Reinhold, and beyond it the crater Lansberg. Apollo 12's landing site lies to the upper left of Lansberg.

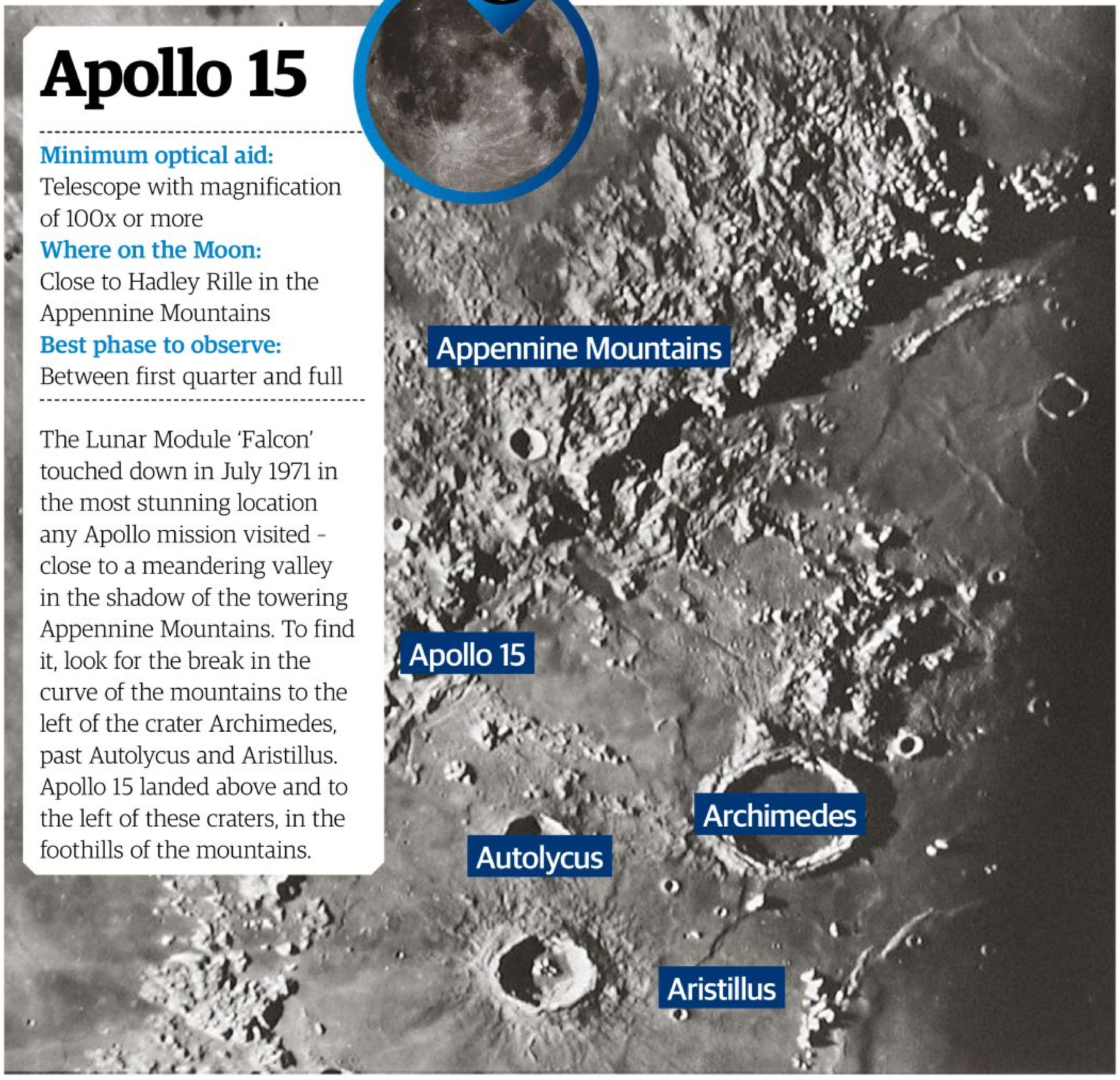




Apollo 14

Minimum optical aid: Telescope with magnification of 50x or more
Where on the Moon: Fra Mauro, close to crater Ptolmaeus
Best phase to observe: Between first quarter and full

The Apollo 14 landing site is close to one of the most impressive and most photographed 'crater chains' on the Moon. Having found Arzachel, Alphonsus and Ptolmaeus, jump across to the right of Ptolmaeus to the ring-like crater Parry. The Apollo 14 landing site is just to the lower right of this crater.



Apollo 15

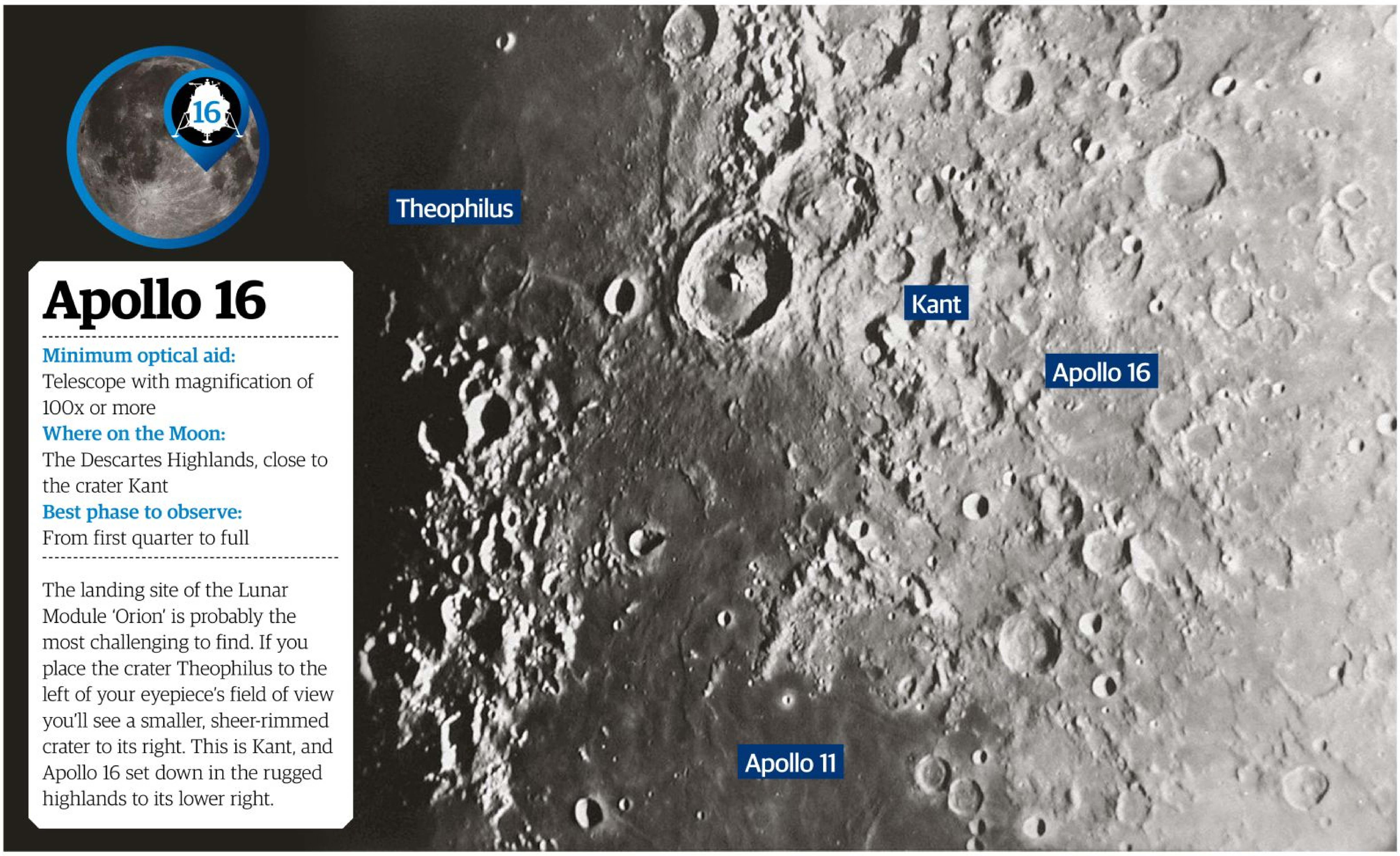
Minimum optical aid:
Telescope with magnification of 100x or more
Where on the Moon:
Close to Hadley Rille in the Appennine Mountains
Best phase to observe:
Between first quarter and full

The Lunar Module 'Falcon' touched down in July 1971 in the most stunning location any Apollo mission visited – close to a meandering valley in the shadow of the towering Appennine Mountains. To find it, look for the break in the curve of the mountains to the left of the crater Archimedes, past Autolycus and Aristillus. Apollo 15 landed above and to the left of these craters, in the foothills of the mountains.

Looking back on those glory days, it seems like the writings of science fiction. It was an age when enormous rockets, gleaming white, thundered into the sky, roaring like dragons and carrying brave explorers across the gulf of space, travelling much further than we could possibly go today. In 2019 astronauts like Tim Peake can travel no further than the International Space Station, which orbits the Earth at a distance of a mere few hundred miles. Between 1969 and 1972 six Apollo missions took teams of three astronauts across a quarter of a million miles of space to the Moon, set two of them down on its barren surface and brought them all home safely again. A seventh mission, Apollo 13, famously failed to land on the Moon, but the astronauts survived a flight around the Moon using their lunar lander as a lifeboat and returned to Earth safely.

Today those daring missions are as fascinating as ever – but for very different reasons. Many people – and not just 'Hoaxers' – have asked why astronomers don't turn the Hubble telescope towards the Moon to take photos of the Apollo spacecraft, simply because it would be a cool thing to do. It's because not even the great Hubble

> "Today those daring missions are as fascinating as ever"



Apollo 16

Minimum optical aid:
Telescope with magnification of 100x or more
Where on the Moon:
The Descartes Highlands, close to the crater Kant
Best phase to observe:
From first quarter to full

The landing site of the Lunar Module 'Orion' is probably the most challenging to find. If you place the crater Theophilus to the left of your eyepiece's field of view you'll see a smaller, sheer-rimmed crater to its right. This is Kant, and Apollo 16 set down in the rugged highlands to its lower right.

© USRA

> "Not even the great Hubble would be able to see a four-metre (13-foot) Apollo spacecraft on the Moon"

Apollo 17

Minimum optical aid: Telescope with magnification of 100x or more
Where on the Moon: Taurus Littrow Valley
Best phase to observe: First quarter to full

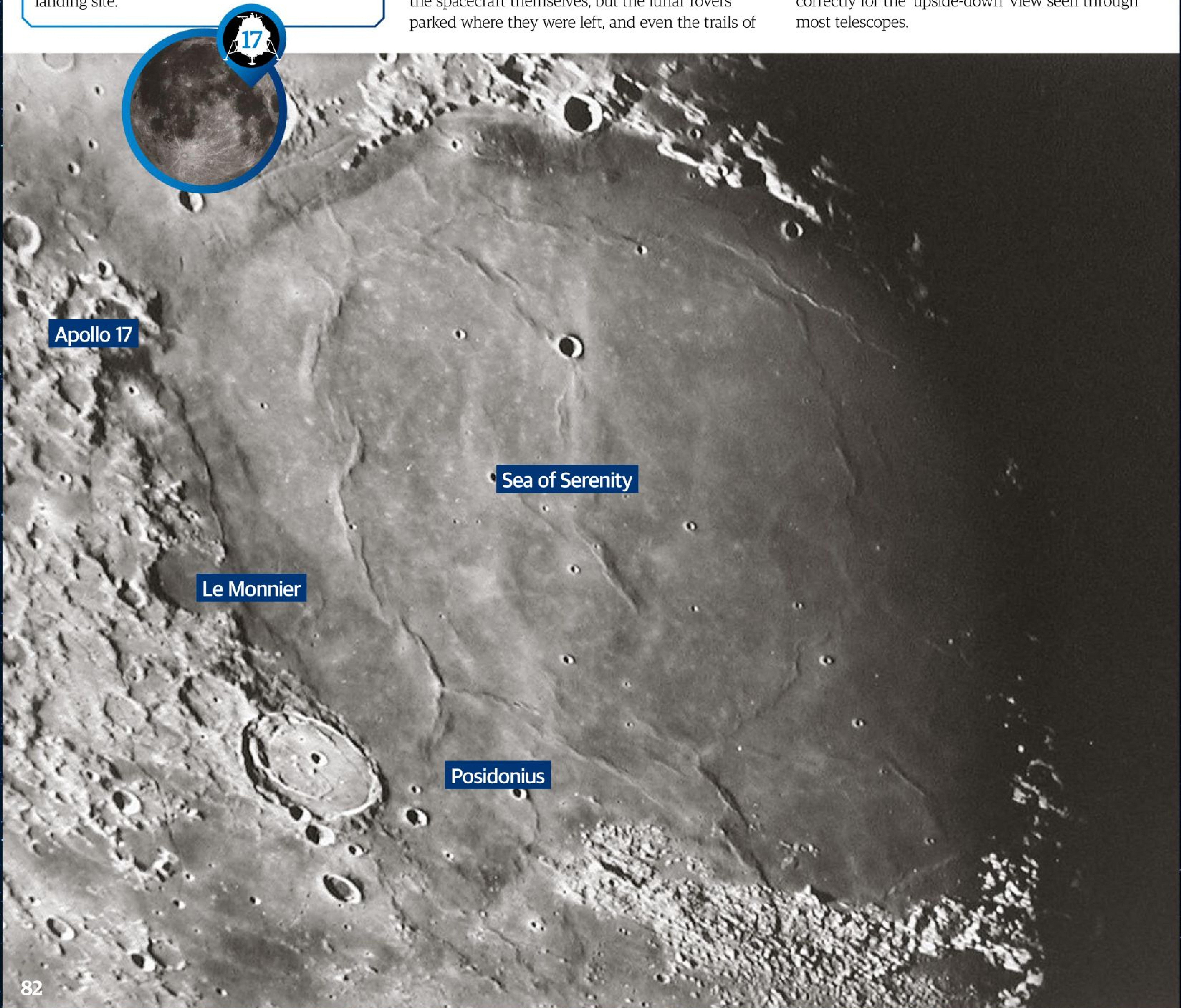
The final Apollo mission in December 1972 saw the Lunar Module 'Challenger' land in a notch-like 'bay' on the southern shore of the Sea of Serenity. To find it, put the shallow crater Posidonius at the bottom of your field of view. Follow the shoreline 'up' past the semi-circular Le Monier crater. As far on again is the Apollo 17 landing site.

would be able to see a four-metre (13-foot) Apollo spacecraft on the Moon. Hubble is essentially a light bucket, designed to collect the faint, ghostly light of faraway galaxies, nebulae and planets. It can't zoom in on things in its own backyard. In fact, if a football stadium was magically transported to the Moon, Hubble couldn't even see that – it just hasn't got the resolving power necessary.

To see the Apollo hardware you would have to go to the Moon, either landing next to the actual spacecraft as rovers might do later this year or next, or look down on them from orbit. The Lunar Reconnaissance Orbiter (LRO) has done just that, and has taken amazing images of the Apollo landing sites from orbit showing not just the spacecraft themselves, but the lunar rovers parked where they were left, and even the trails of bootprints left in the lunar dust by the explorers. If you were hoping to see actual Apollo hardware on the Moon through your telescope, you've no chance, unfortunately. However, you can see the Apollo landing sites from your back garden if your telescope is good enough – and we're going to tell you how, and where, to find them.

First you need to know the general areas of the landing sites on the Moon, and the key to doing that is to think of the Moon as the face of a clock, with 12 o'clock at the top and 6 o'clock at the bottom. You can then find the rough areas of each mission's landing site quite easily using the charts included in this guide.

Having found the general areas of the landing sites, you can then zoom in on those to pin-down the actual landing sites more accurately. You do this by looking for certain obvious features the landing sites were close to, such as a large crater, a range of hills or a valley – something like that. Again the charts given here will help you. The individual charts supplied are oriented correctly for the 'upside-down' view seen through most telescopes.



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Deep sky challenge

Sizzling summer's clusters and nebulae

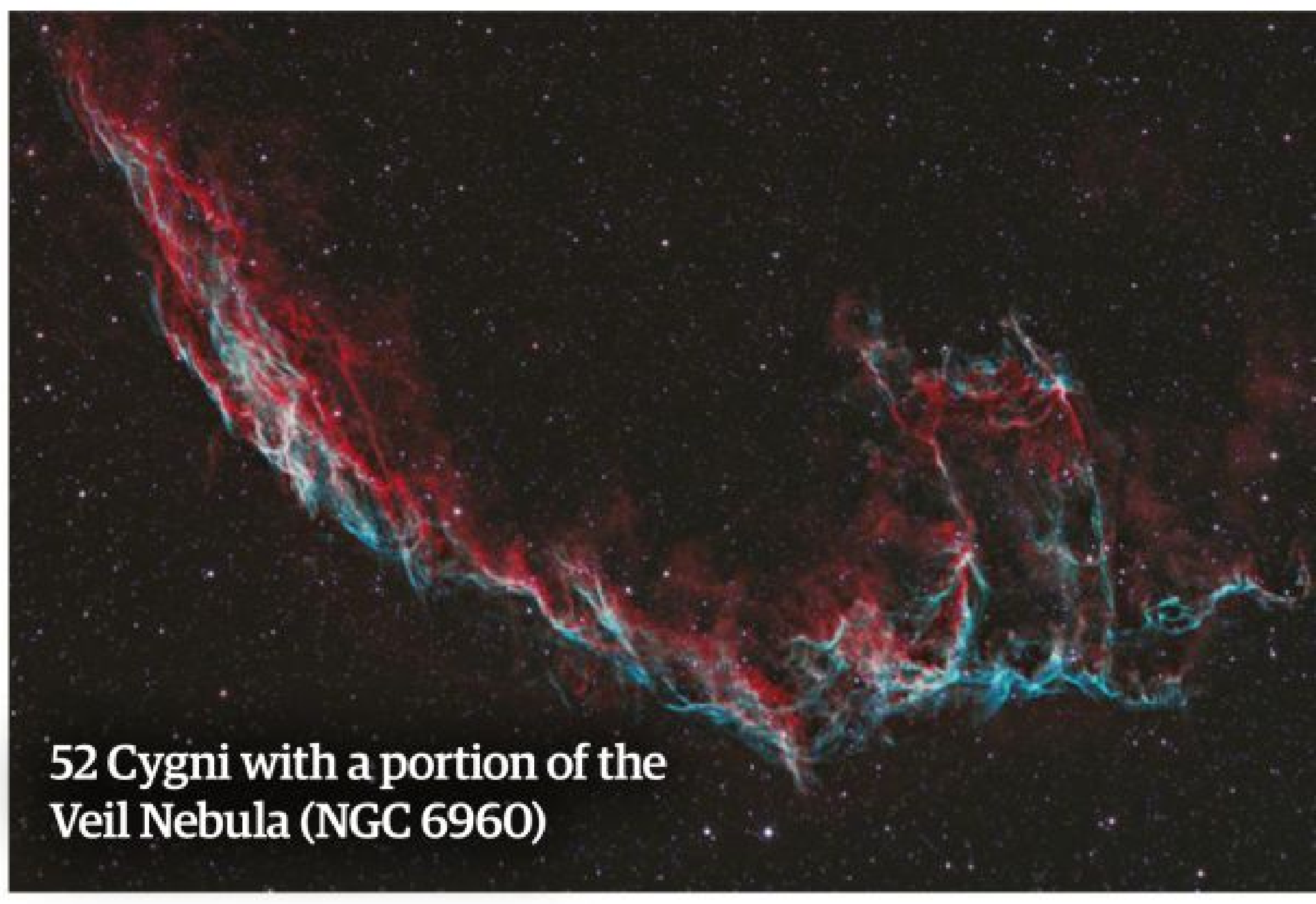
The Cygnus Wall in the North America Nebula (NGC 7000)

Glittering star clusters, a dead star's corpse and a beautiful double star can all be seen this month

Many sky-watchers think the summer sky is just too bright to allow observation of faint and fuzzy deep-sky objects, but if you stay up late enough the sky is just dark enough to let you see some lovely sights through a telescope.

Around one or two in the morning – providing the sky isn't lit up with a display of bright blue and silver noctilucent clouds – a telescope will give you very pleasing views of some of astronomy's most famous objects.

Although the broad, frothy band of the Milky Way dominates the sky, running right through the centre of Cygnus the Swan, or the Northern Cross, cutting it and the whole sky in half, embedded in it are subtly coloured nebulae, regions where stars are being born. Elsewhere can be seen the ghostly remains of dying or dead stars and much more. Even a small telescope will give you a beautiful view of one of the loveliest and most popular double stars in the whole sky.



52 Cygni with a portion of the Veil Nebula (NGC 6960)

Veil Nebula (NGC 6992)

1 Messier 39

A loose open cluster, roughly triangular in shape and the same angular diameter as the Moon. Best seen in small 'scopes using low magnification.

2 North America Nebula (NGC 7000)

Although this famous emission nebula covers as much sky as four full Moons and can be seen in binoculars, a telescope is needed to pick out its shape. Lower magnifications work best.

3 Messier 29

This magnitude-6.6 open cluster contains only a few scattered stars, forming the shape of an open box. Small to medium telescopes pick it out well from the background sky.

4 Veil Nebula (Sharpless 103)

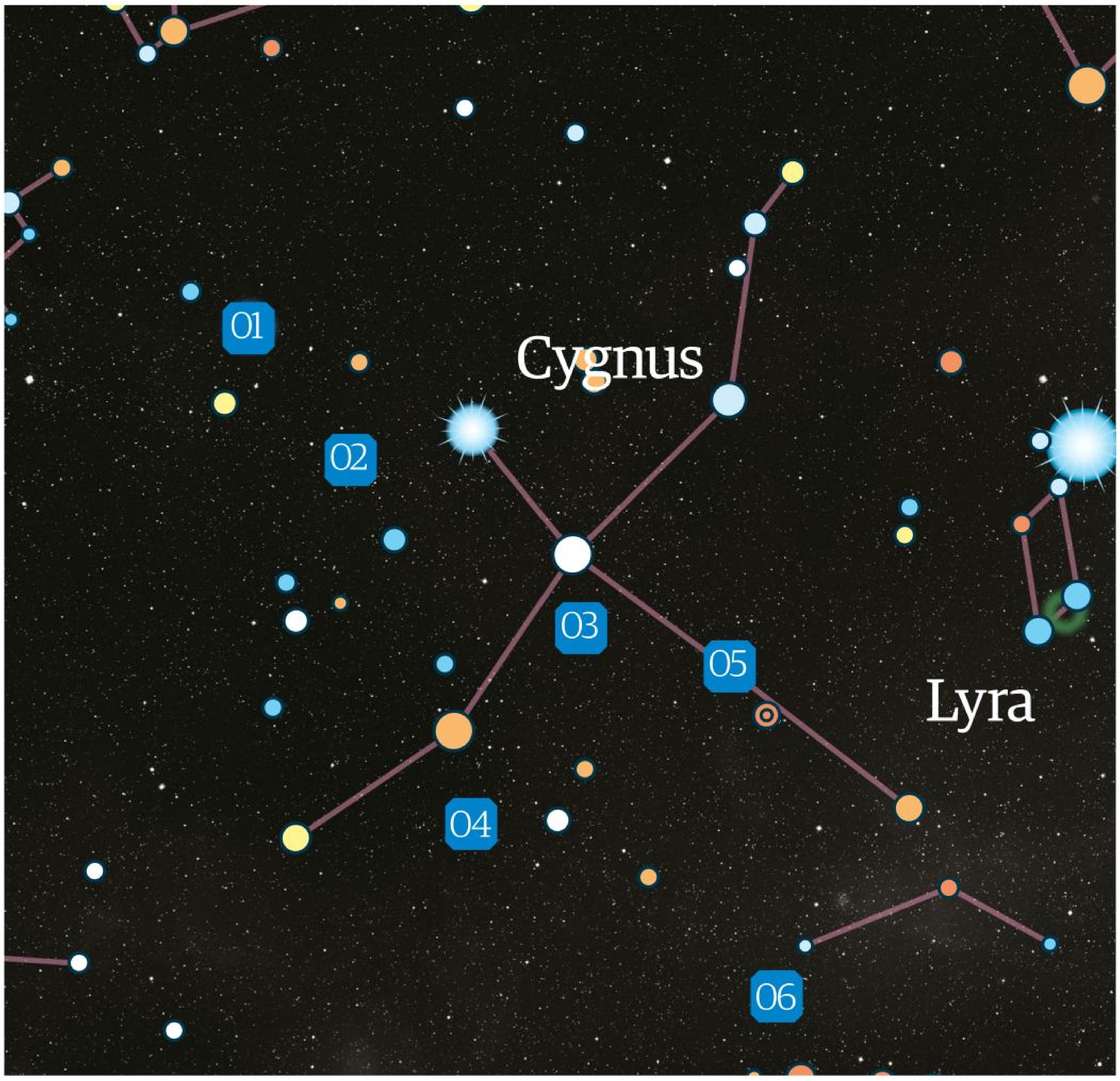
It consists of two arcs of faint gas, the remains of a star that blew up between 5,000 and 8,000 years ago. A medium-aperture telescope is needed to show structure and hints of colour.

5 Albireo (Beta Cygni)

One of the most beautiful double stars in the sky, any telescope splits Albireo into a 3rd-magnitude gold star and a magnitude 4.7 sapphire-hued star, 20" apart.

6 Dumbbell Nebula (Messier 27)

The famous Dumbbell Nebula is just a small smudge in small telescopes. Medium- and large-aperture telescopes show its twin lobes of blue-green gas.



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The Northern Hemisphere

A gaggle of galaxies, star clusters and nebulae grace the August skies, offering an exquisite selection for stargazers

There's an impressive array of targets suitable for observers armed with binoculars, telescopes or for those who are just content with gazing upon the night sky with the unaided eye.

Galaxies and star clusters are abundant, but it's the nebulae within constellations such as Cygnus and Lyra that are the objects to look to this month. The Ring Nebula (M57), the Pelican Nebula, young and dense planetary nebula NGC 7027, reflection nebula NGC 6914 and the 'blinking planetary' nebula NGC 6826 are particularly impressive, providing observing and imaging opportunities for astronomers.

Using the sky chart

This chart is for use at 22:00 (BST) mid-month and is set for 52° latitude.

01 Hold the chart above your head with the bottom of the page in front of you.

02 Face south and notice that north on the chart is behind you.

03 The constellations on the chart should now match what you see in the sky.

Magnitudes

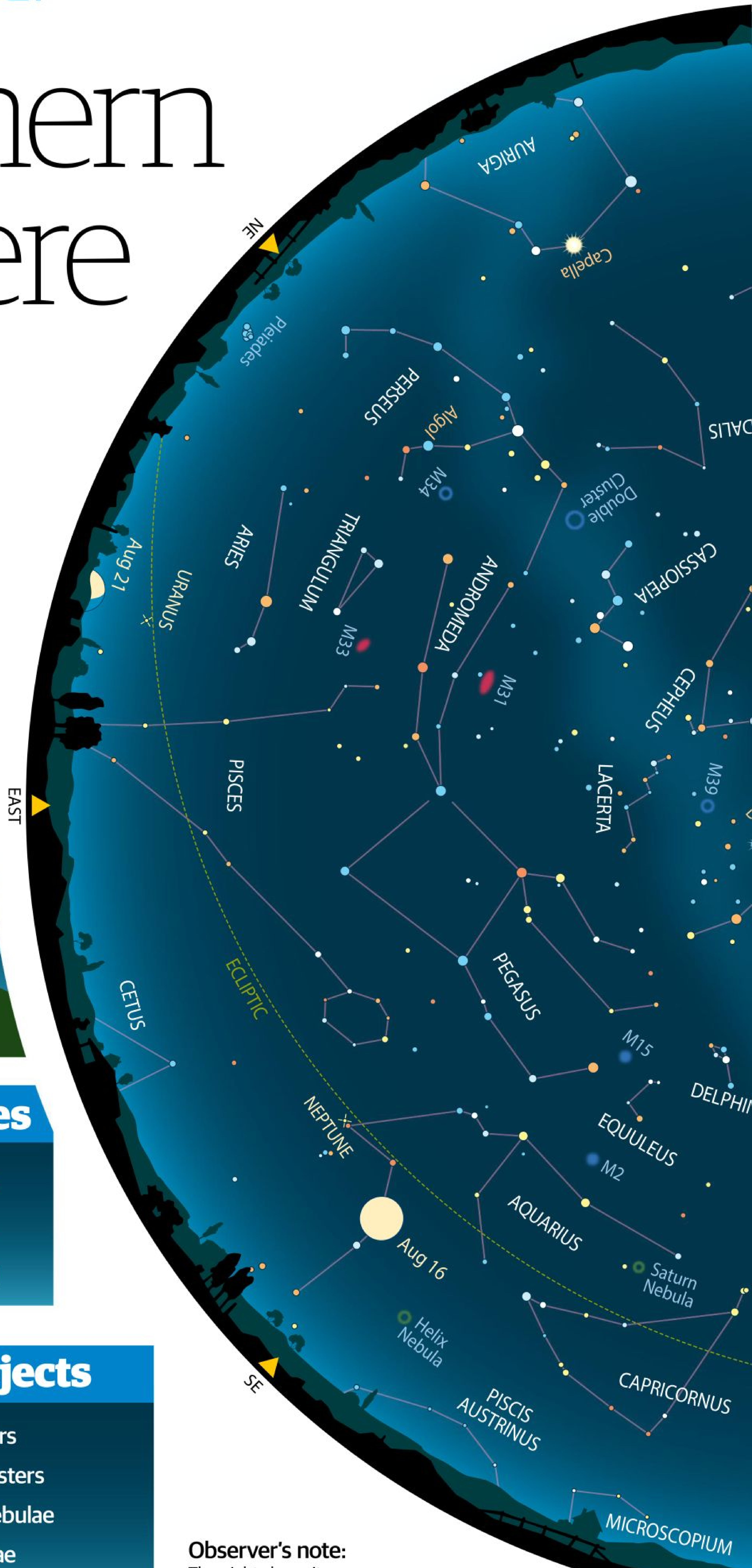
- ● Sirius (-1.4)
- ● -0.5 to 0.0
- ● 0.0 to 0.5
- ● 0.5 to 1.0
- ● 1.0 to 1.5
- • 1.5 to 2.0
- • 2.0 to 2.5
- • 2.5 to 3.0
- • 3.0 to 3.5
- • 3.5 to 4.0
- · 4.0 to 4.5
- · Fainter
- ◉ Variable star

Spectral types

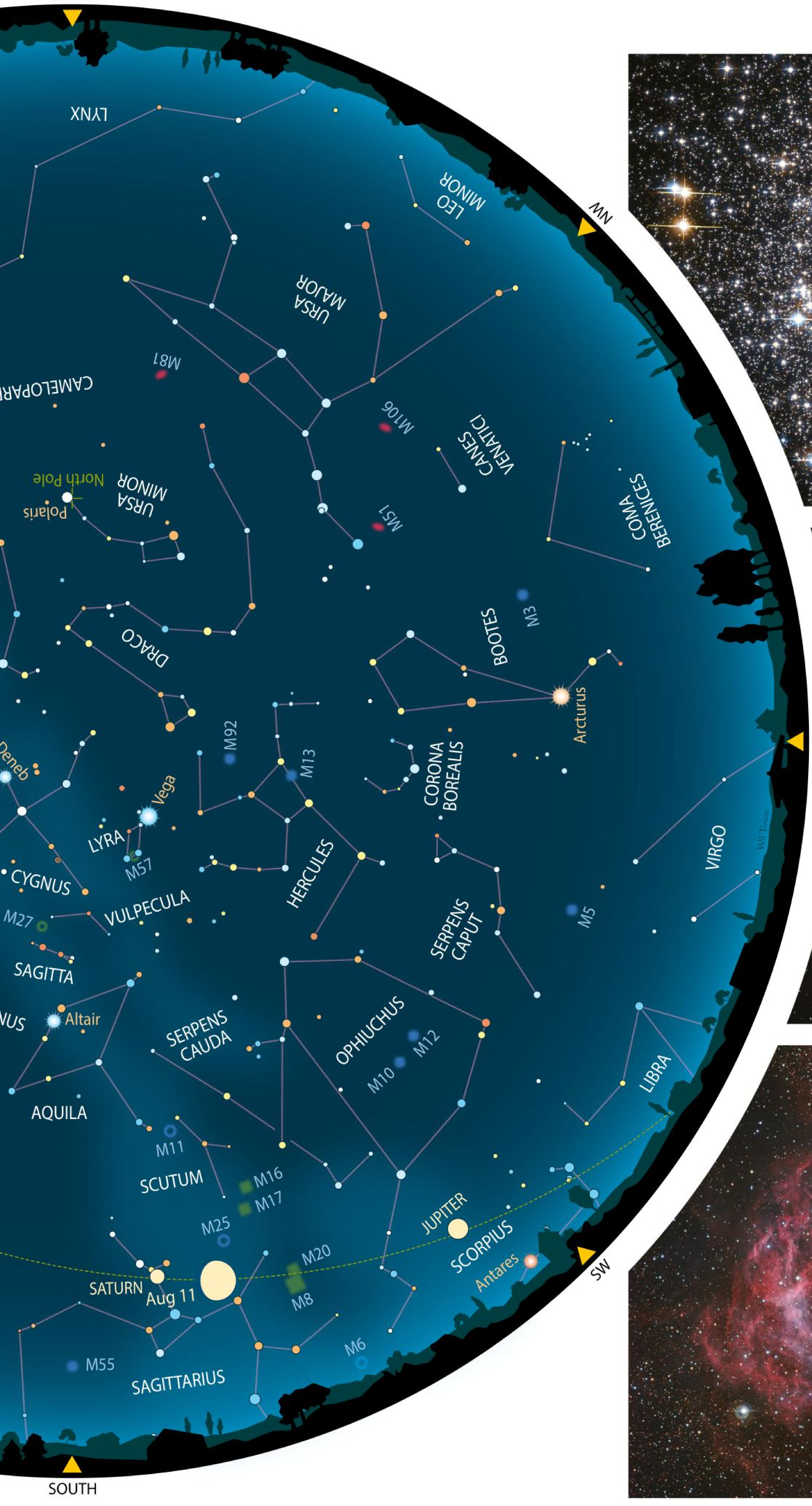
●	O-B	●	G
●	A	●	K
●	F	●	M

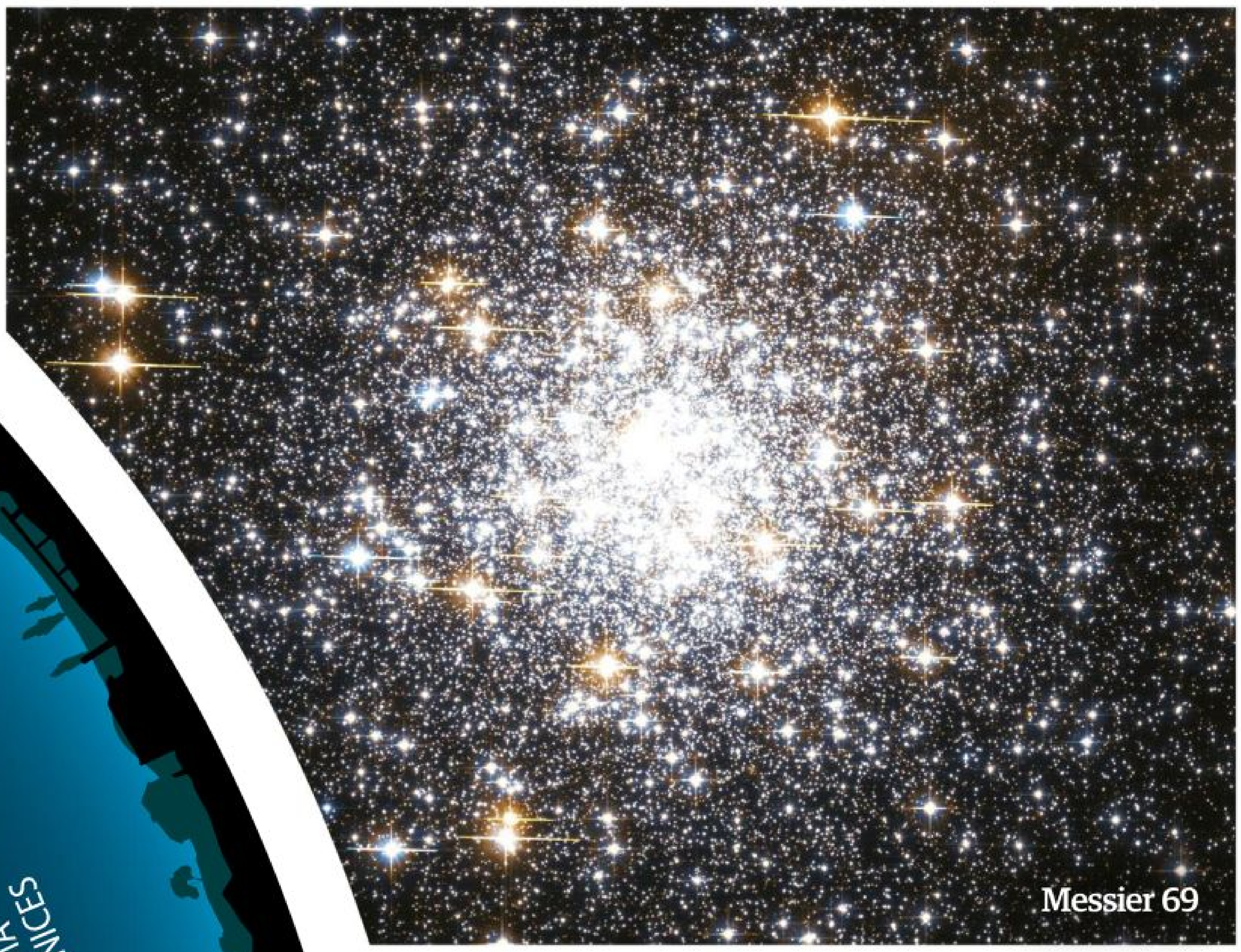
Deep-sky objects

- ○ Open star clusters
- ● Globular star clusters
- ■ Bright diffuse nebulae
- ○ Planetary nebulae
- ● Galaxies

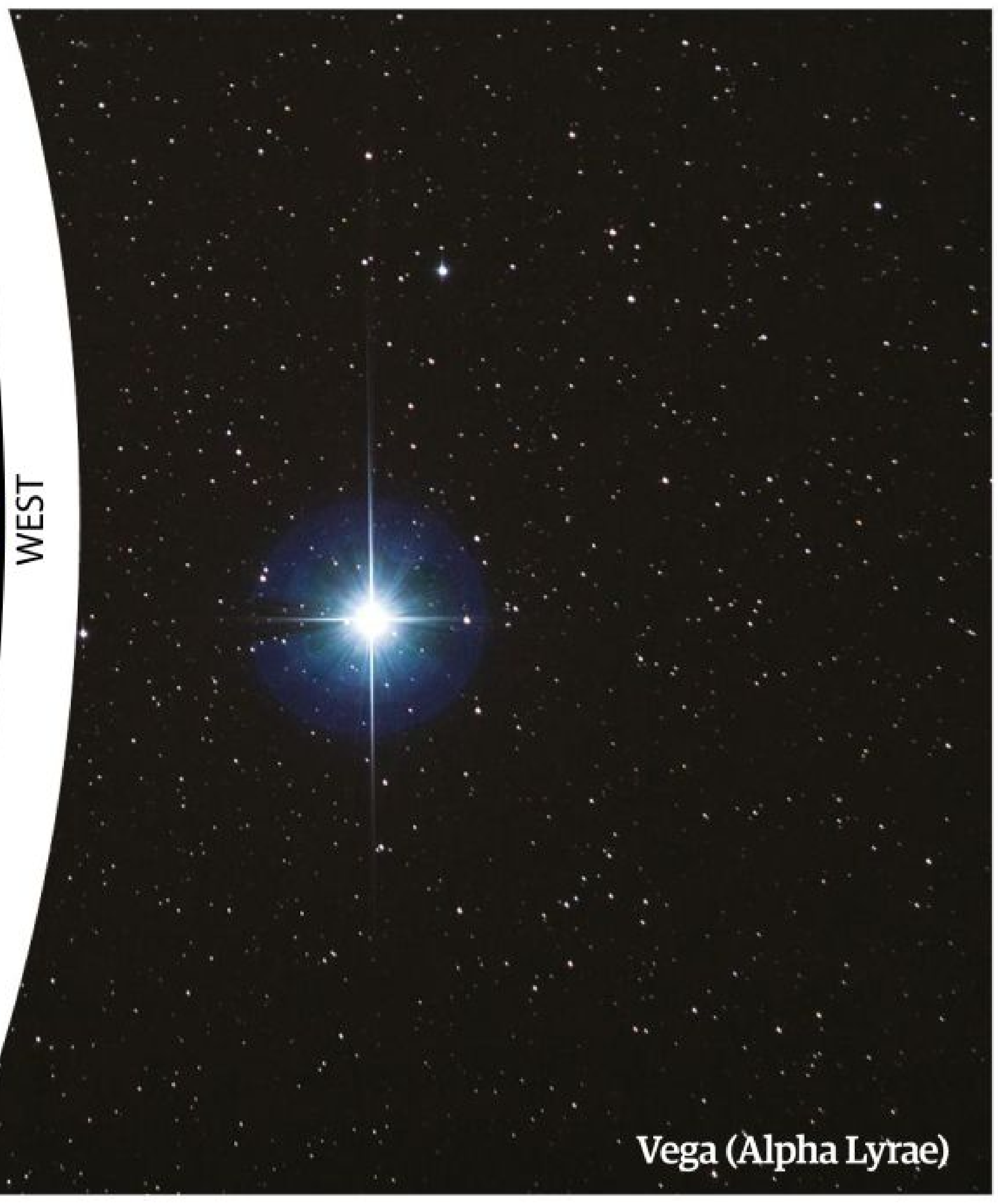


Observer's note:
The night sky as it appears on 16 August 2019 at approximately 22:00 (BST).





Messier 69



Vega (Alpha Lyrae)

Omega Nebula (Messier 17)

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Astroshots of the month

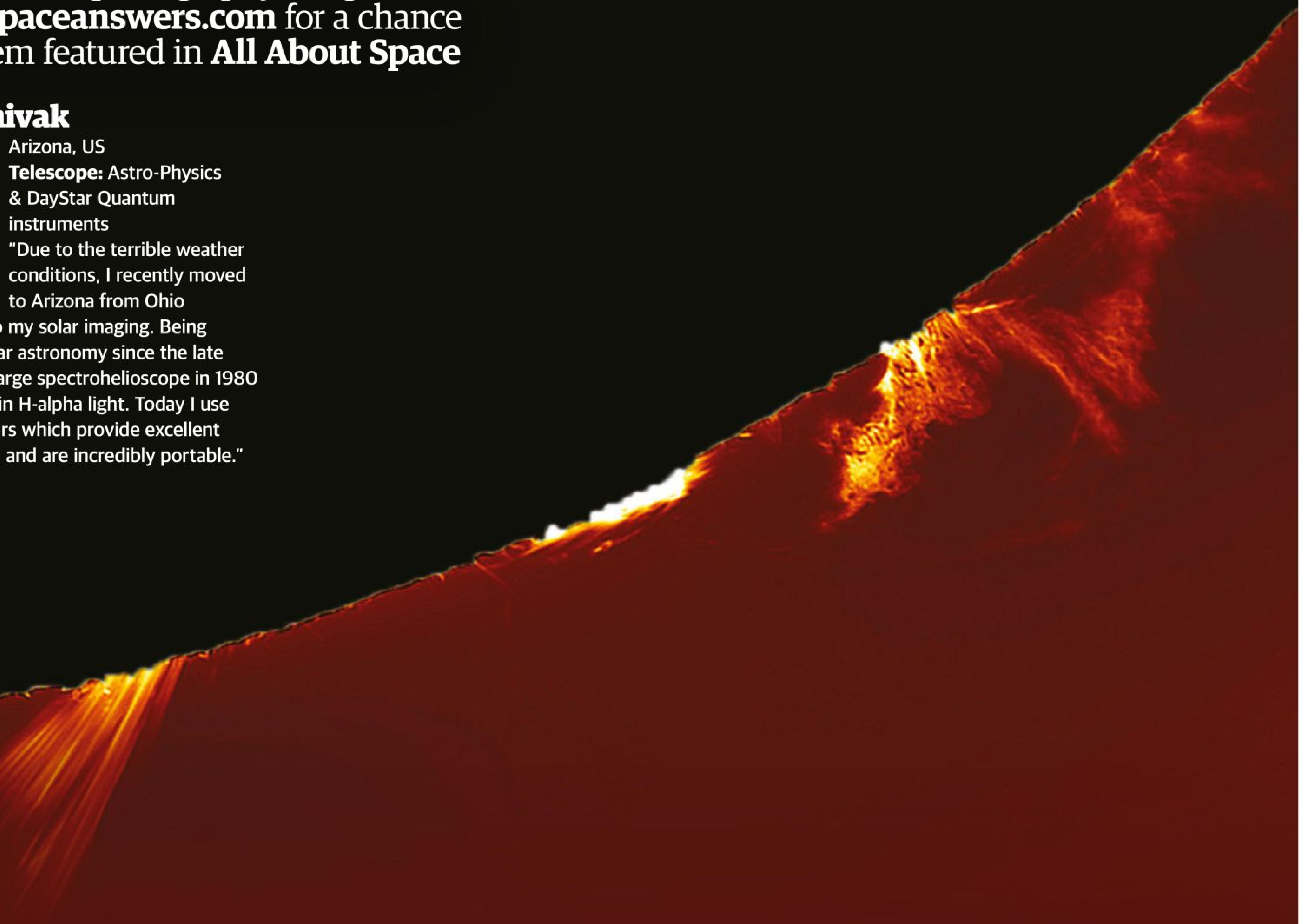
Send your astrophotography images to **space@spaceanswers.com** for a chance to see them featured in **All About Space**

Randy Shivak

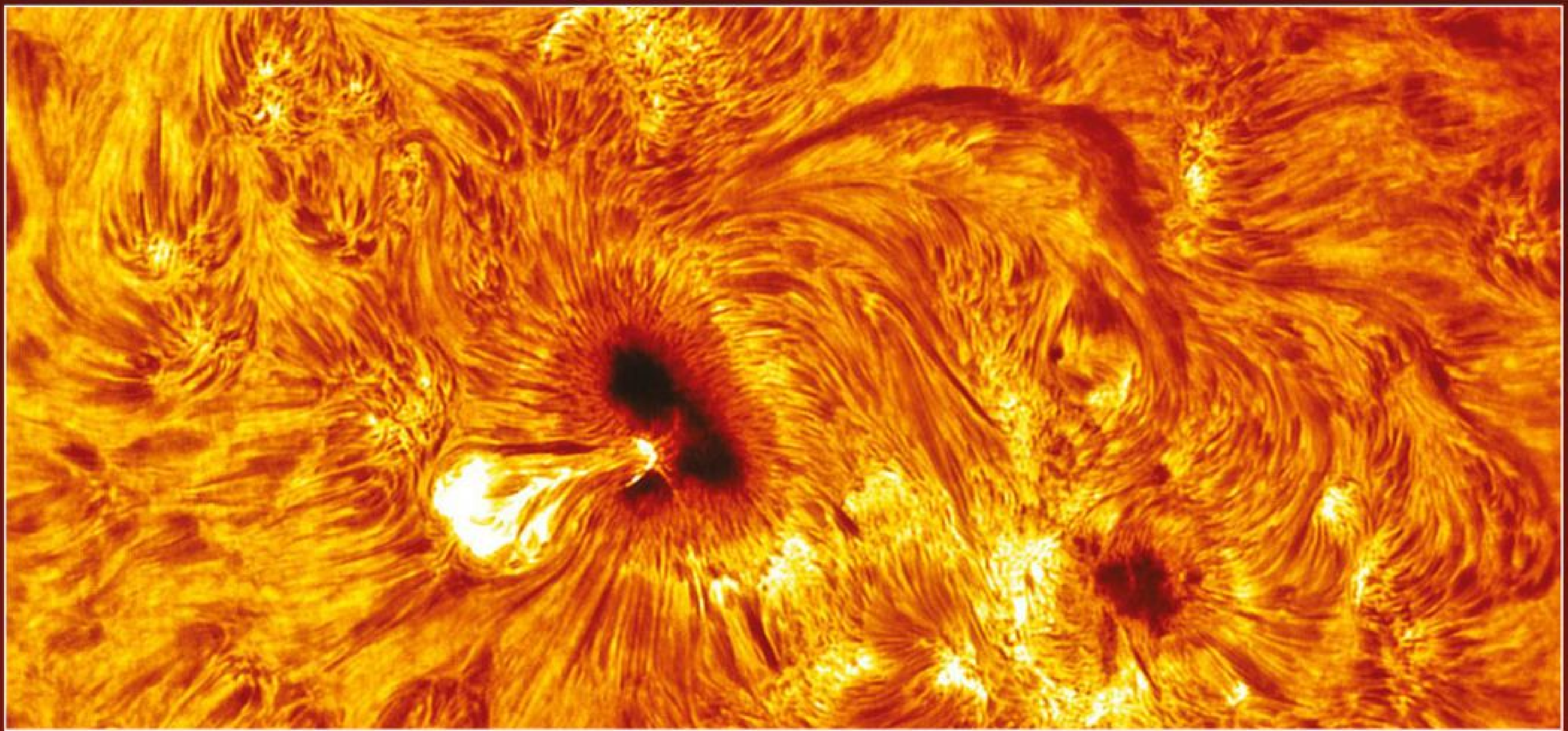
Arizona, US

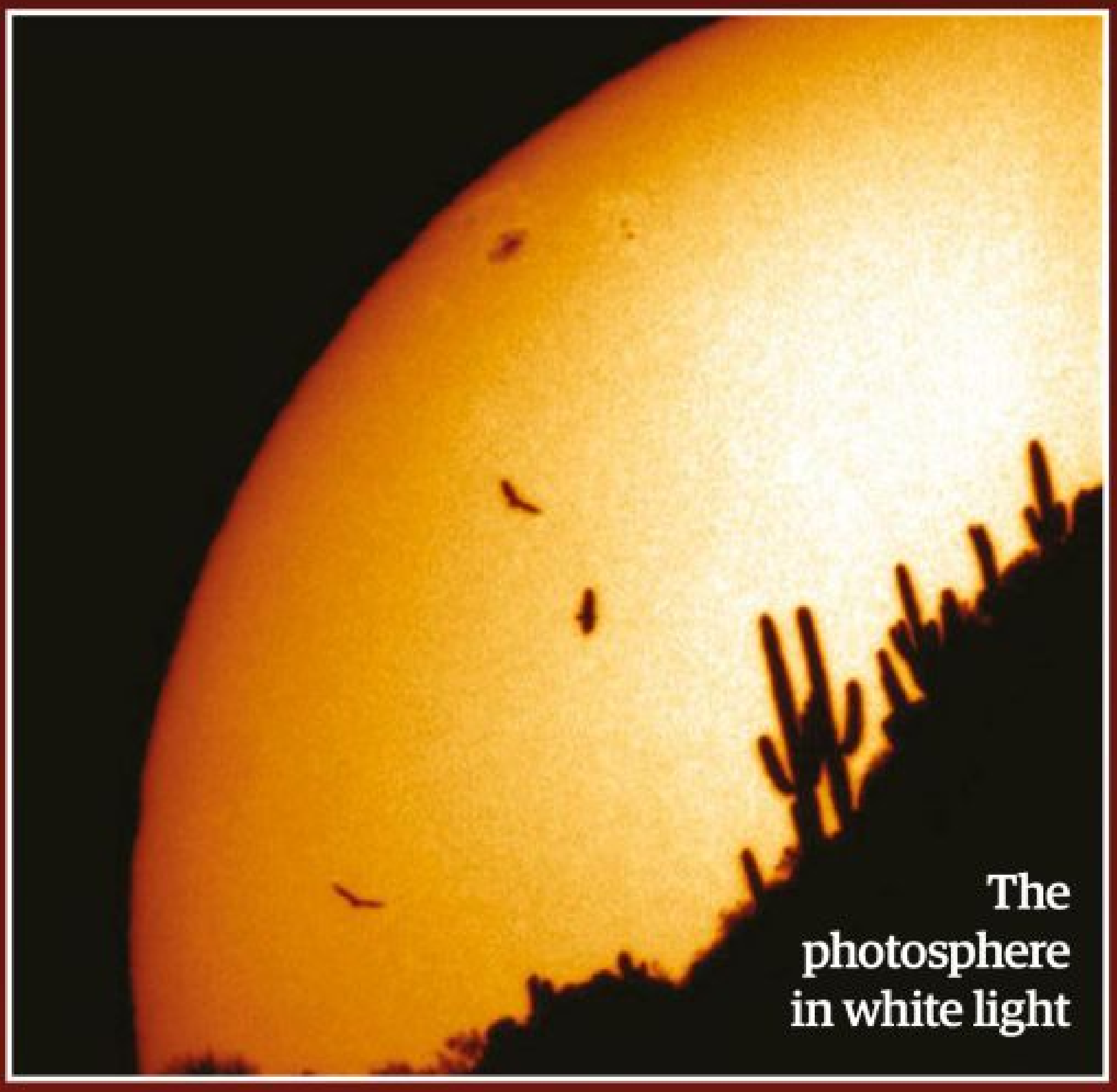
Telescope: Astro-Physics & DayStar Quantum instruments

"Due to the terrible weather conditions, I recently moved to Arizona from Ohio specifically to do my solar imaging. Being interested in solar astronomy since the late 1960s, I built a large spectrohelioscope in 1980 to view the Sun in H-alpha light. Today I use narrowband filters which provide excellent views of the Sun and are incredibly portable."

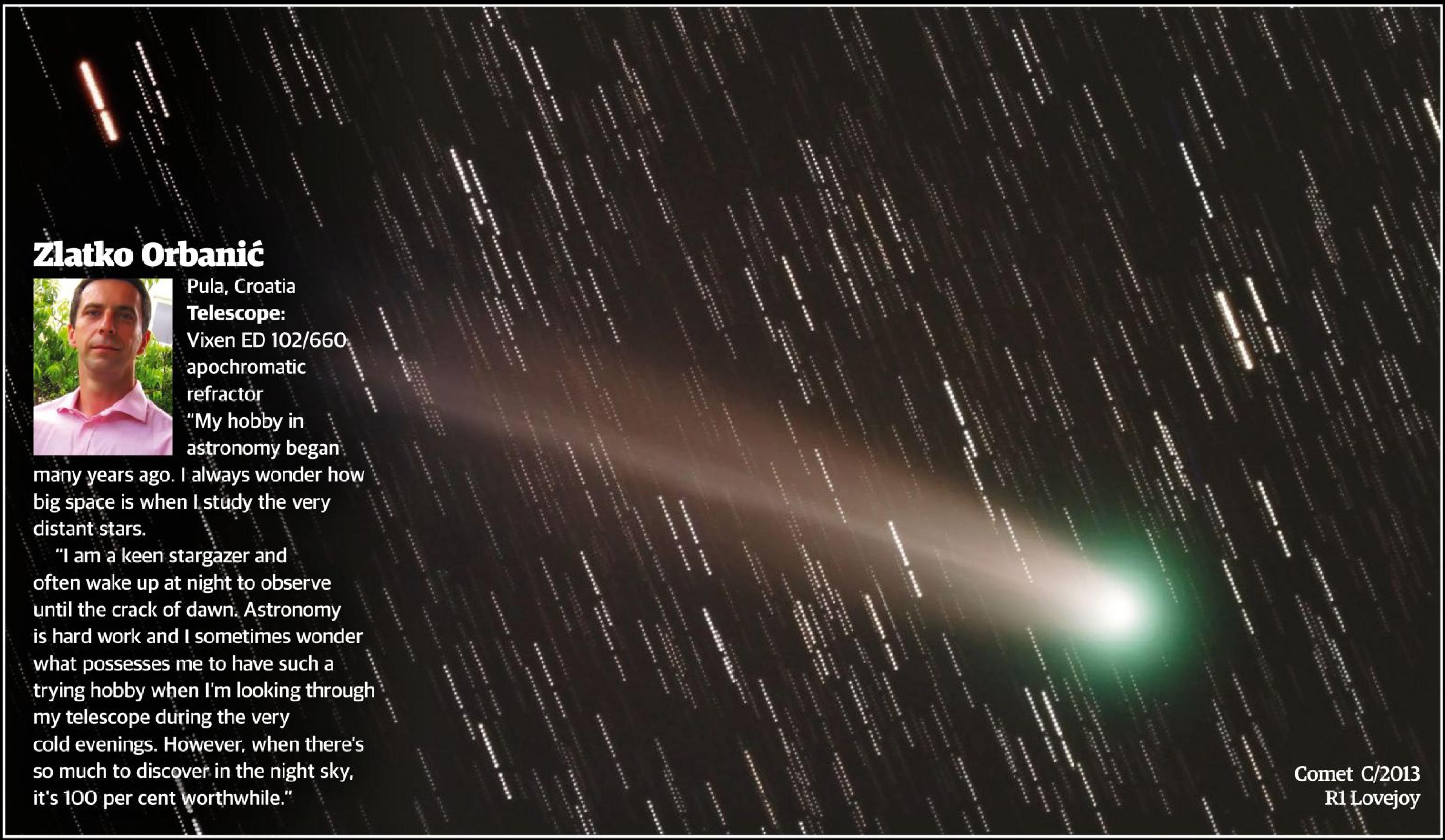


Solar prominence (above) and sunspot group 1731 (below)





The photosphere in white light



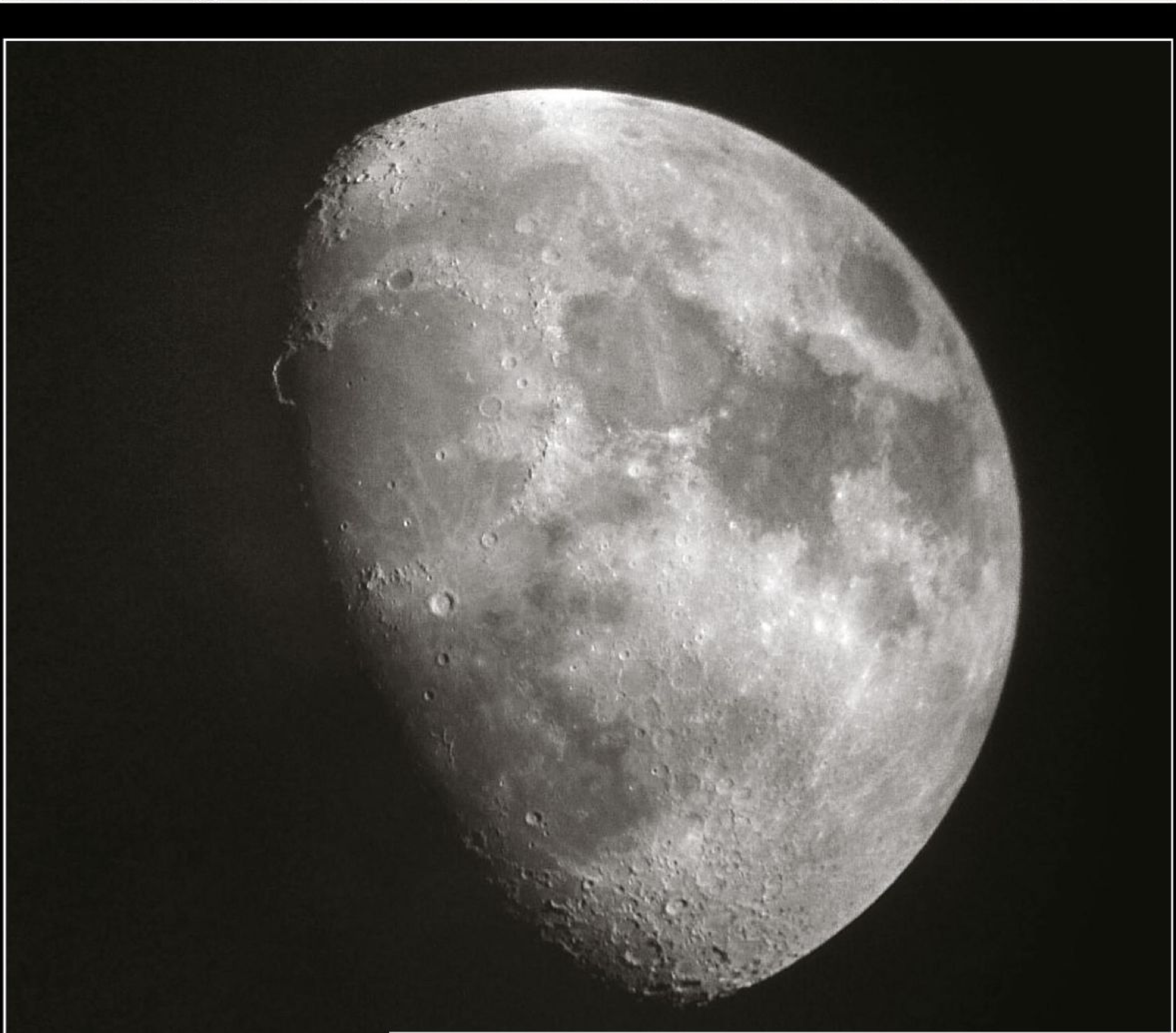
Zlatko Orbanić

Pula, Croatia
Telescope:
Vixen ED 102/660 apochromatic refractor

"My hobby in astronomy began many years ago. I always wonder how big space is when I study the very distant stars.

"I am a keen stargazer and often wake up at night to observe until the crack of dawn. Astronomy is hard work and I sometimes wonder what possesses me to have such a trying hobby when I'm looking through my telescope during the very cold evenings. However, when there's so much to discover in the night sky, it's 100 per cent worthwhile."

Comet C/2013 R1 Lovejoy



Carl Martin

County Durham, England
Telescope:
Celestron Astromaster 70 AZP

"I enjoy observing the Moon and planets. Receiving my first telescope for Christmas 2012 – just an entry-level one to get my bearings – I have toured the night sky. I observe Saturn on occasion and enjoy star-hopping my way around the heavens. I am looking to upgrade my telescope to an equatorial mount for deep-sky

> "I have observed Saturn on occasion and really enjoy star-hopping"

Send your photos to... @spaceanswers @ space@spaceanswers.com

Meade Polaris 114 EQ

A breeze to set up and sturdy enough to withstand slightly breezy conditions, this reflector allows for pleasing observations of a wide variety of targets

Telescope advice

Cost: £250 ($311)
From: Currys
Type: Reflector
Aperture: 114mm
Focal length: 1,000mm

Best for...

- Intermediate
- Small budget
- Solar System targets
- Lunar surface
- Bright deep-sky
- Basic astrophotography

Meade has provided a telescope that boasts a superior build over other instruments within its price range. Finished off to a high standard, the manufacturer of the Polaris 114 EQ has provided a very good selection of eyepieces as well as a 2x Barlow lens for low, medium and high magnification that not only saves a dent in the bank balance, saving the observer from having to buy countless accessories, but also ensures that the amateur astronomer has everything they need for an evening under the night sky. Similar to the telescope itself, the accessories are well-made with no signs of finishing glue or stickiness that we've encountered with other telescopes below the £300 ($373) price range.

There were a couple of negative points, however: the red-dot finder's construction isn't the best, being made of plastic, but it certainly got the job done. Also, the AutoStar instructional DVD that comes with the telescope is unfortunately unable to be used on a Macintosh computer.

Assembly is quick and easy. While Meade always provides a comprehensive manual with each of its telescopes, we found the setting up very intuitive to the point that we rarely needed to refer to it, making the 114 EQ ideal for those wanting a telescope that's quick and easy to set up, doesn't want their observing time cut into or those who are in the early stages of learning their way around the night sky. If you're used to using a 'scope that employs an alt-azimuth mount then you may find the setting up and use of the Polaris 114 EQ's German equatorial quite tricky. However, full guidance is provided in the supplied manual, which is packed with very useful information. If you're unsure of how to get the best out of an equatorial mount then we advise doing a bit of research on them before you get stuck into your observations. Polar aligning is an easy task once the observer knows how to use this type of mount.

We had an excellent run of clear skies throughout our test period in June, and combined with a dark-sky site the night sky was our oyster. Being a reflector the Polaris 114 EQ allows you to choose between a selection of deep-sky and Solar System targets – small-aperture refractors seem to fare better with bright targets, such as the planets and the Moon. Observing just before dawn gave us the opportunity to make the most of gas giant Jupiter, shining at a dazzling magnitude of -2.58. Views of the planet were clear and crisp thanks to the reflector's optics, which have been smothered with anti-reflection coating. Through the field of view we were treated to a pale disc, with the Galilean moons strung out either side of the gas giant's limbs as points of light. Peripheral vision afforded us the opportunity to spot the planet's equatorial bands.

We were keen to enhance our viewing experience so included a selection of coloured filters – orange,

Below left: The red-dot finder is flimsy but does the job when navigating the night sky

Below right: The Polaris 114 EQ employs a German equatorial mount

“Views of the planet were clear and crisp thanks to the reflector’s optics”

light red, dark red, dark blue and violet – fitting these to the supplied eyepieces which provide an easy-screw barrel to make threading attachments a breeze. Using a high-power eyepiece pushed the reflector's limiting magnification too far, producing blurry images of the king of the Solar System, so we recommend using low-power eyepieces when viewing closer planetary targets.

Moving to the northwest in the evening we made brief contact with Mars. As expected, views of the planet were crisp and clear, the Red Planet appearing as a salmon-pink disc. Meanwhile, a waning crescent Moon with 15 per cent illumination allowed us to obtain views of the rugged lunar surface, with pin-sharp sights of craters and lunar mare of exquisite contrast.

If you want to try your hand at some very basic astrophotography then the equatorial mount allows for sturdy photography using either a smartphone or DSLR camera. Tracking is also easy with the Polaris 114 EQ using the setting circles for Right Ascension and Declination and the slow-motion controls for a pleasantly smooth experience. If you aren't keen on continually turning the knobs to track planets and other targets during lengthy observations then we recommend purchasing a motor for the mount.

Deep-sky objects such as bright star clusters could be observed with ease using the telescope's good optical system. The Great Globular Cluster in Hercules, also known as Messier 13, appeared as a small, fuzzy ball through the field of view, while a selection of double stars could be split very easily.

The Polaris 114 EQ is able to provide views of objects beyond our Solar System as well as inside it, making it suitable as a more advanced beginner 'scope or for those who are keen observers of a variety of targets and don't want to be restricted to one kind of astronomical target.

Left: A 2x Barlow lens and two eyepieces are supplied

WIN

WORTH £225!

MEADE LIGHTBRIDGE MINI 130

Ready to go outside the box, touring the night sky has never been simpler with this latest offering from Meade Instruments and Hama UK Ltd

The ultimate grab-and-go telescope, the LightBridge Mini provides the same, high-quality observing experience of its larger truss-tube Dobsonian cousins without compromising portability – pull it out the box and you're ready to begin your stargazing experience in seconds.

Boasting an impressive 130mm parabolic aperture with a 650mm focal length, the LightBridge Mini features a simple point-and-look design that makes navigating the sky effortless. Its light-gathering abilities provide superb views of the Moon, planets and a selection of deep-sky objects, such as galaxies and nebulae. The Vixen-style dovetail offers versatility, allowing you to switch mounts, while the parabolic mirror provides images with stunning contrast and clarity.

To be in with the chance of winning, all you have to do us answer this question:

In which hemisphere does the constellation of Crux (the Cross) belong?

A: Southern Hemisphere

B: Both

C: Northern Hemisphere

Competition ends on 15 August 2019

Enter via email at **space@spaceanswers.com** or by post to **All About Space competitions, Richmond House, 33 Richmond Hill, Bournemouth, BH2 6EZ**

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Congratulations to Shaun Bradberry, who is the winner of astronomy kit worth over £1000!

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Apollo 11 gift guide

Celebrate 50 years of the Moon landing with one of these stunning keepsakes, made especially to commemorate humankind's greatest achievement

LEGO Lunar Lander

Cost: £84.99 ($99.99)
From: LEGO

The giant of building blocks, LEGO, has now released a 1,087-piece building set that recreates NASA's Apollo 11 Lunar Lander. The 'Eagle' has landed in stores around the world, and is also available online. Builders of all ages can now have a hands-on approach to lunar exploration and become inspired by the event that occurred exactly 50 years ago this July.

This collectible LEGO Creator Expert model comes equipped with all the pieces to construct the lander's descent and ascent stage, including gold-coloured landing pads, opening camera, laser hatches, a ladder and a very detailed interior to the Lunar Module that lifted Neil Armstrong and Buzz Aldrin off the surface of the Moon. Speaking of the famous duo, their mini figures also come with the set, NASA-decorated as they plant the flag of the United States.

The Case Astronaut Knife M-1

Cost: £183.32 ($232.99)
From: W.R. Case & Sons Cutlery Company

One instrument used by astronauts that has well and truly dipped under the radar has been the survival knife, Case's Astronaut Knife M-1, which has been rereleased as a limited edition for the occasion. But why would an astronaut need a 43-centimetre (17-inch), high-carbon, stainless steel machete blade with a smooth, white synthetic handle?

In the days of the Gemini and Apollo programs, NASA commissioned the production of a knife which would be stowed in the Command Module in case of emergencies and kept along with other items as part of a survival pack. NASA needed a knife that had a blunt base, an impressive ultra-lightweight and robust design and did not emit fumes to maintain the purity of the limited air supply.

The World's First Moon Dome Crown Coin

Cost: £9.95 ($12.65)
From: The Bradford Exchange

This is not your average coin: it's a commemorative, world-first edition of a solid-dome coin. On one side it features the face of Her Majesty, the Queen of England, and on the reverse curves into the face of the Moon as seen from Earth.

This incredible feat in coin-minting portrays the Moon's surface in incredible detail, and you can even spot the Sea of Tranquillity where Armstrong and Aldrin laid their metaphorical hat for all of 21 hours. As this coin has been minted for such a special occasion, only 9,999 were made available to people around the world – so be sure not to miss out!

Fisher Bullet Space Pen – Apollo 11 special edition

Special Edition £34.95 ($44.42)
Limited Edition: £754.99 ($959.55)
From: Fisher Space Pens

Fisher Space Pens are not like any other pen. When Paul Fisher realised that pens struggled to work under freezing temperatures, he developed a pen that could work over a range of temperatures. Fisher Pens work anywhere between -34 to 120 degrees Celsius (-30 to 250 degrees Fahrenheit), at any angle, for three-times as long as a regular pen, underwater and even in zero gravity.

Fisher has unveiled a special-edition pen in a range of colours for the 50th anniversary of Apollo 11 as well as a special-edition AG-7 Space Pen, of which only 500 were made. This addition to the collection includes a commemorative booklet, a coin and the AG-7 itself, made with a genuine piece of 'Kapton' material that was flown on the very mission, sealed in the pen's cap.

Omega Speedmaster Moonwatch

Steel: £7,370 ($9,350)
18-carat Moonshine gold: £26,480 ($33,590)
From: Omega

Want to look extremely suave while celebrating the 50th anniversary of the Apollo 11 Moon landing? Omega has announced a collection of limited-edition Speedmaster watches to celebrate the occasion. This watch is made even more special because although many people know Aldrin was the second person to ever step onto the Moon, not many know he was the first person to do so wearing a watch.

In celebration of the 50th anniversary, Omega has spruced up the Speedmaster watch with a laser-engraved, Moonstone Gold sub-dial of Aldrin as he climbs down the Lunar Module, among other modifications. The company has also released an 18-carat, all-Moonshine gold version that is limited to 1,014 pieces, but the stainless steel has 6,969 (after the year 1969) available at a cheaper cost.

Apollo 11 Technical Cases

Medium £470 ($595)
Small: £415 ($525)
From: Zero Halliburton

Zero Halliburton – famous for its brand of durable, secure and aesthetically pleasing aluminium cases – has paid homage to the Apollo landing by creating small- and medium-sized metal compacts just like the ones that once carried the first loads of lunar rock back to Earth in 1969.

Only 100 cases – 50 in each size – were created to celebrate the occasion, and each comes with a embroidered baseball cap and dust bag. The case itself is built to provide the best protection for your contents, the same way that Armstrong and Aldrin needed to protect the priceless lunar rock as they returned it for important scientific testing. Zero Halliburton has also created a five-part online campaign titled 'Precious Cargo', which tells the story of the first-ever lunar sample return and how Zero Halliburton made a very unique contribution.

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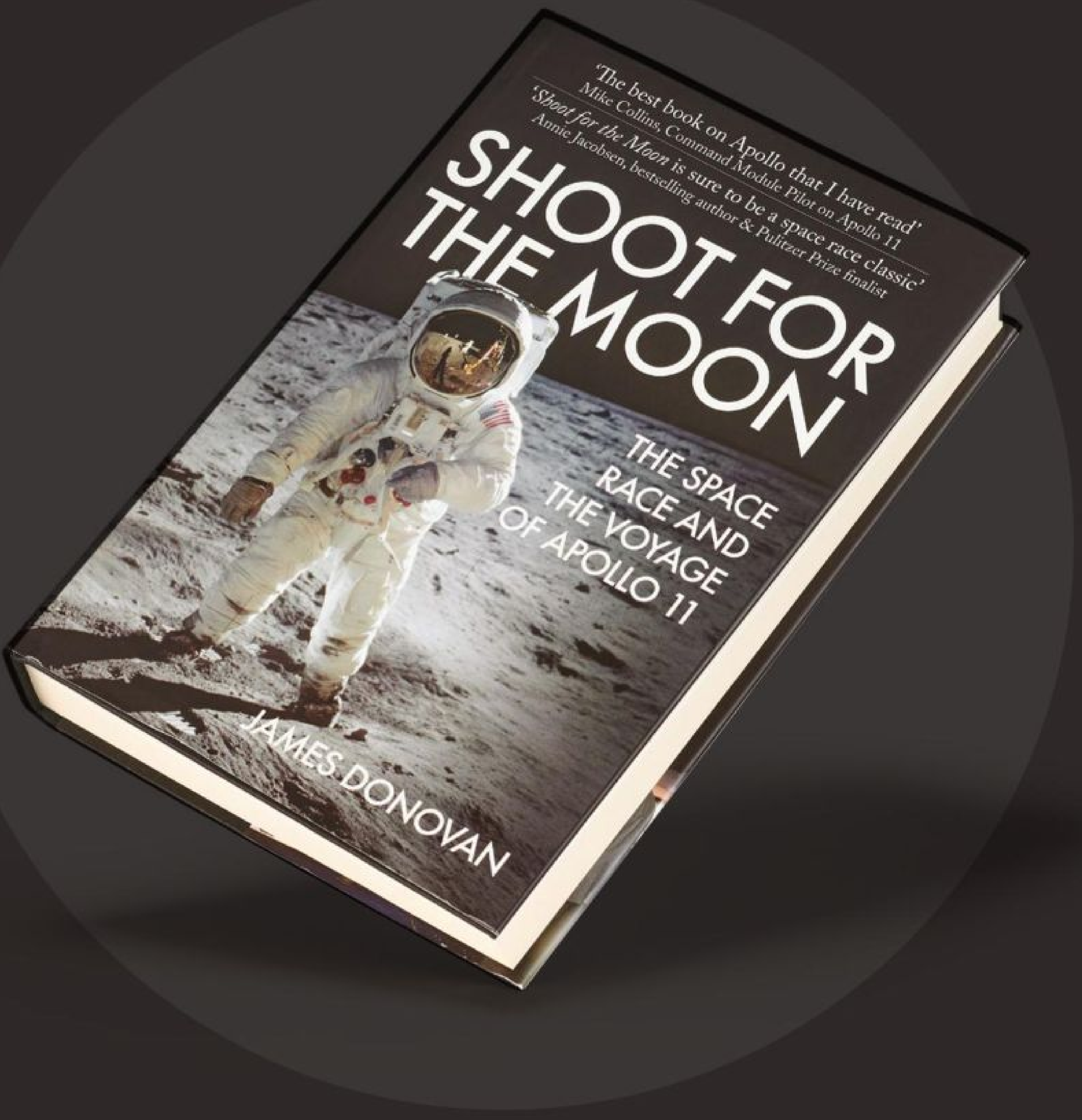

'The best book on Apollo that I have read'
Mike Collins, Command Module Pilot on Apollo 11
'Shoot for the Moon is sure to be a space race classic'
Annie Jacobsen, bestselling author & Pulitzer Prize finalist
SHOOT FOR THE MOON
THE SPACE RACE AND THE VOYAGE OF APOLLO 11
JAMES DONOVAN

Shoot for the Moon

Cost: £25 ($31.69)
From: Amberley Books

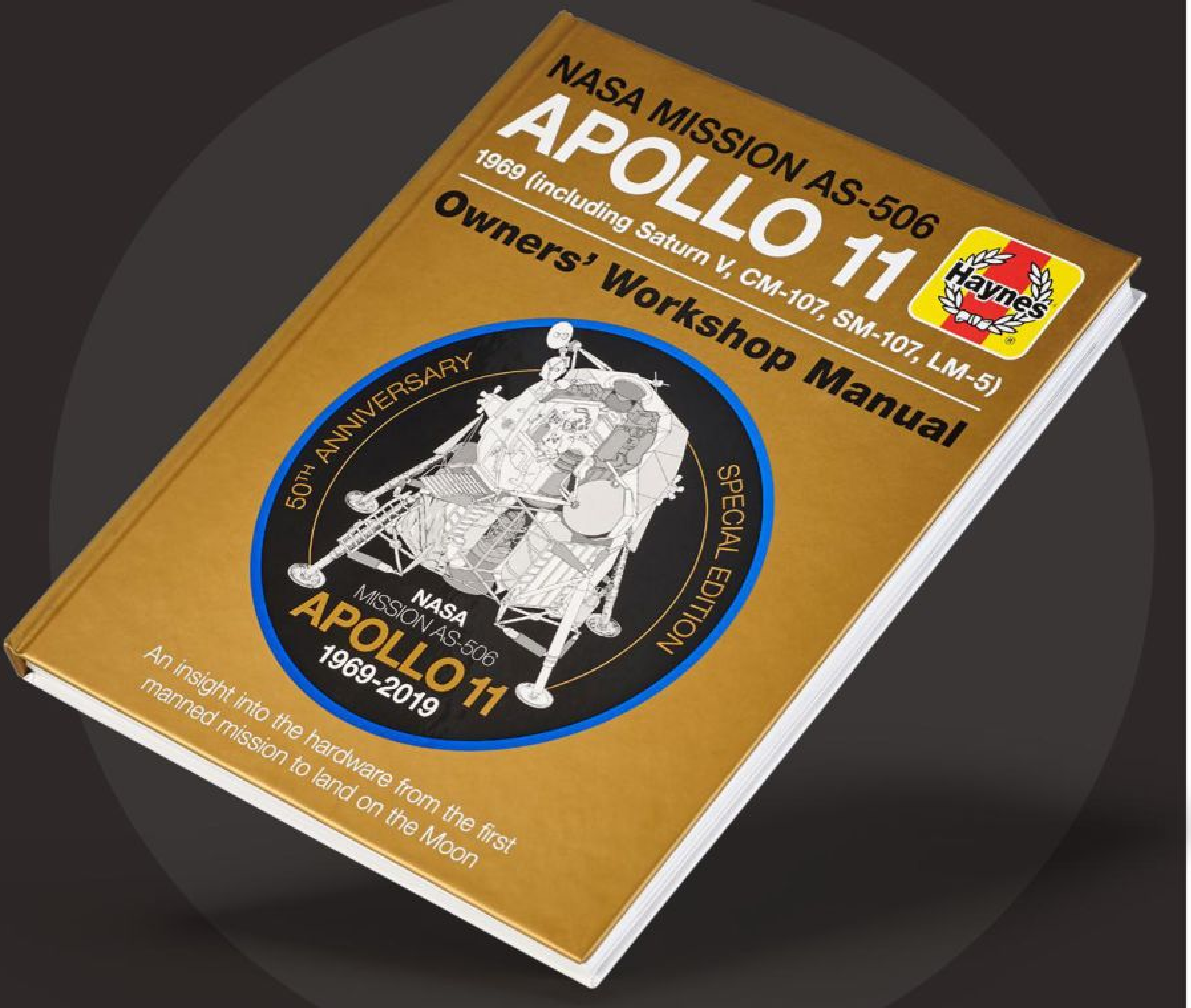
50 years after the Apollo 11 mission made history, this book tells the story of the astronauts, flight controllers and engineers who made it happen. On 20 July 1969, Neil Armstrong and Buzz Aldrin became the first humans to walk on the Moon, a moment ingrained in modern memory. Perhaps the world's greatest technological achievement – and a triumph of spirit and ingenuity – the Apollo 11 mission and the Apollo program were a mammoth undertaking involving more than 410,000 men and women dedicated to winning the Space Race with the Soviets.

Seen through the eyes of those who lived it, *Shoot for The Moon* reveals the dangers, the challenges and the sheer determination that defined not only Apollo 11, but also the Mercury and Gemini missions that made it possible. Both sweeping and intimate, based on exhaustive research and dozens of fresh interviews, this is the definitive – and thrilling – account of one of humankind's most extraordinary feats of exploration.

FirstScope tabletop telescope

Cost: £65 ($82.40)
From: Royal Observatory Greenwich

FirstScope is an ideal entry-level astronomical telescope. It is very easy to observe with: the user simply navigates the night sky by moving the tube in the direction of their desired object, making the viewing experience a snap! The compact design ensures it's easy enough to take with you on your next outdoor adventure. FirstScope is also stylish enough to be a decorative fixture on your bookshelf or desk. The portable and lightweight table-top design makes it easy to store, transport and set up your FirstScope telescope. The instrument is a wonderful keepsake for anyone interested in astronomy.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Haynes
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NASA
MISSION AS-506
APOLLO 11
1969-2019
An insight into the hardware from the first manned mission to land on the Moon

Apollo 11: 50th Anniversary Edition

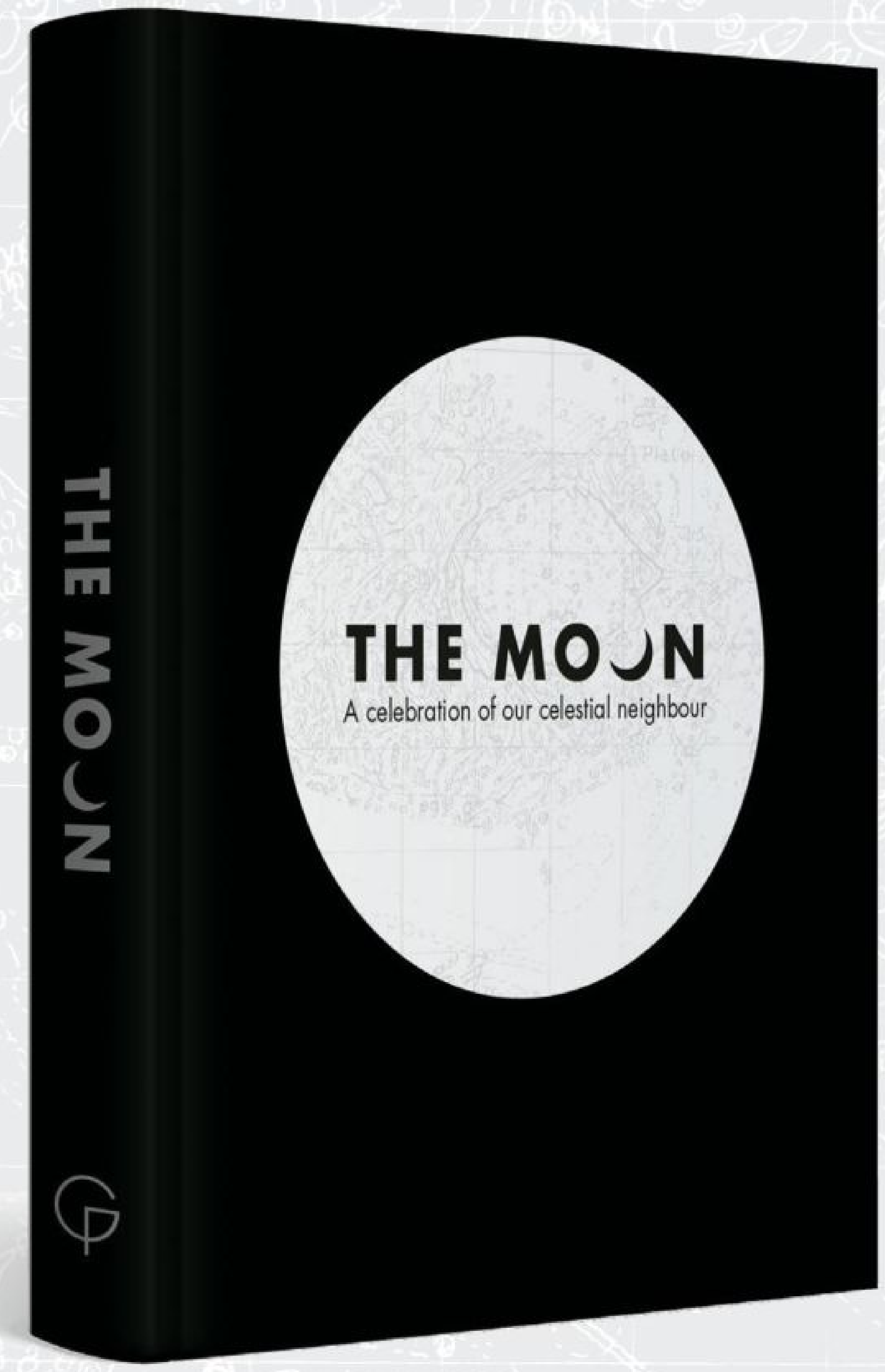
Cost: £22.99 ($29.10)
From: Haynes Publishing

On 20 July 1969, US astronauts Neil Armstrong and Buzz Aldrin became the first men to walk on the Moon.

Christopher Riley and Phil Dolling tell the story of the Apollo 11 mission and the 'space hardware' that made it all possible. This manual looks at the evolution and design of the mighty Saturn V rocket, the Command and Service Modules and the Lunar Module. It describes the spacesuits worn by the crew and their special life-support and communications systems. We learn about how the Apollo 11 mission was flown – from launch procedures to 'flying' the Saturn V and the 'LEM', from Moon walking to the Earth re-entry procedure.

This celebratory anniversary edition features a new look at the legacy of Apollo 11, and a look forward to future manned Moon missions and deep-space exploration.

Marking the 50th anniversary of Neil Armstrong's 'small step', this beautiful book explores people's fascination with our only natural satellite.



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William Shepherd

He was the very first commander of the International Space Station

William Shepherd completed four spaceflights in his time at NASA

©NASA

His might not be a household name, but a big name nonetheless, William Shepherd played his part in NASA's transition from the continuous launches of the Space Shuttle program into the constant presence of the International Space Station (ISS) in low-Earth orbit.

Shepherd was born on 26 July 1949 in Oak Ridge, Tennessee, United States. He later gained his Bachelor of Science degree in aerospace engineering from the US Naval Academy in 1971, also earning degrees in ocean engineering and a Master of Science in mechanical engineering from the Massachusetts Institute of Technology (MIT) in 1978. This career path then took him down the route of Navy SEAL – the US Navy's primary special force unit.

Shepherd first applied to become an astronaut in 1980, but unfortunately wasn't successful on his first attempt. It wasn't until he got into the group of 1984 that his training began, gaining him an honourable mention as the first-ever military, non-aviator astronaut selected for NASA astronaut training. All astronauts before him had been aviators, chosen because of their familiarity with high-pressure situations in the sky.

Shepherd got his first taste of the action in December 1988 when he served as mission specialist for the STS-27 Atlantis mission. Two years after he again served as the mission specialist for the STS-41 Discovery mission that deployed NASA's Ulysses space probe, which studied regions near the Sun and Jupiter.

His third and final Space Shuttle mission was the STS-52 Columbia mission in 1992. The following year Shepherd was providing programme management for the ISS – a revolutionary, international architectural endeavour that began assembly in 1998.

Arguably the pinnacle of his astronautic achievements came in October 2000 when he was launched to the newly constructed ISS and became the first commander of the station as part of Expedition 1. Although several countries were contributing to the construction of the ISS, the United States and Russia were pulling most of the financial weight, so along with Russian cosmonauts Sergei Krikalev and Yuri Gidzenko, this three-man crew ran the first lot of important scientific research in the unique low-gravity laboratory that has since had the constant company of humans for over 18 years.

This particular endeavour ended on 21 March 2001, after just short of 141 days in space. Being a veteran of four space flights, Shepherd had clocked up over 159 days in space, with Expedition 1 being the obvious bulk of that time. As of January 2002 Shepherd left NASA in pursuit of more private interests, but his efforts did not go unnoticed.

He received NASA's prestigious Steve Thorne Aviation Award, a United States-issued Congressional Space Medal of Honour and a Russian Federation-issued Medal for Merit in Space Exploration, among other awards.

> "Shepherd first applied to become an astronaut in 1980, but wasn't successful"

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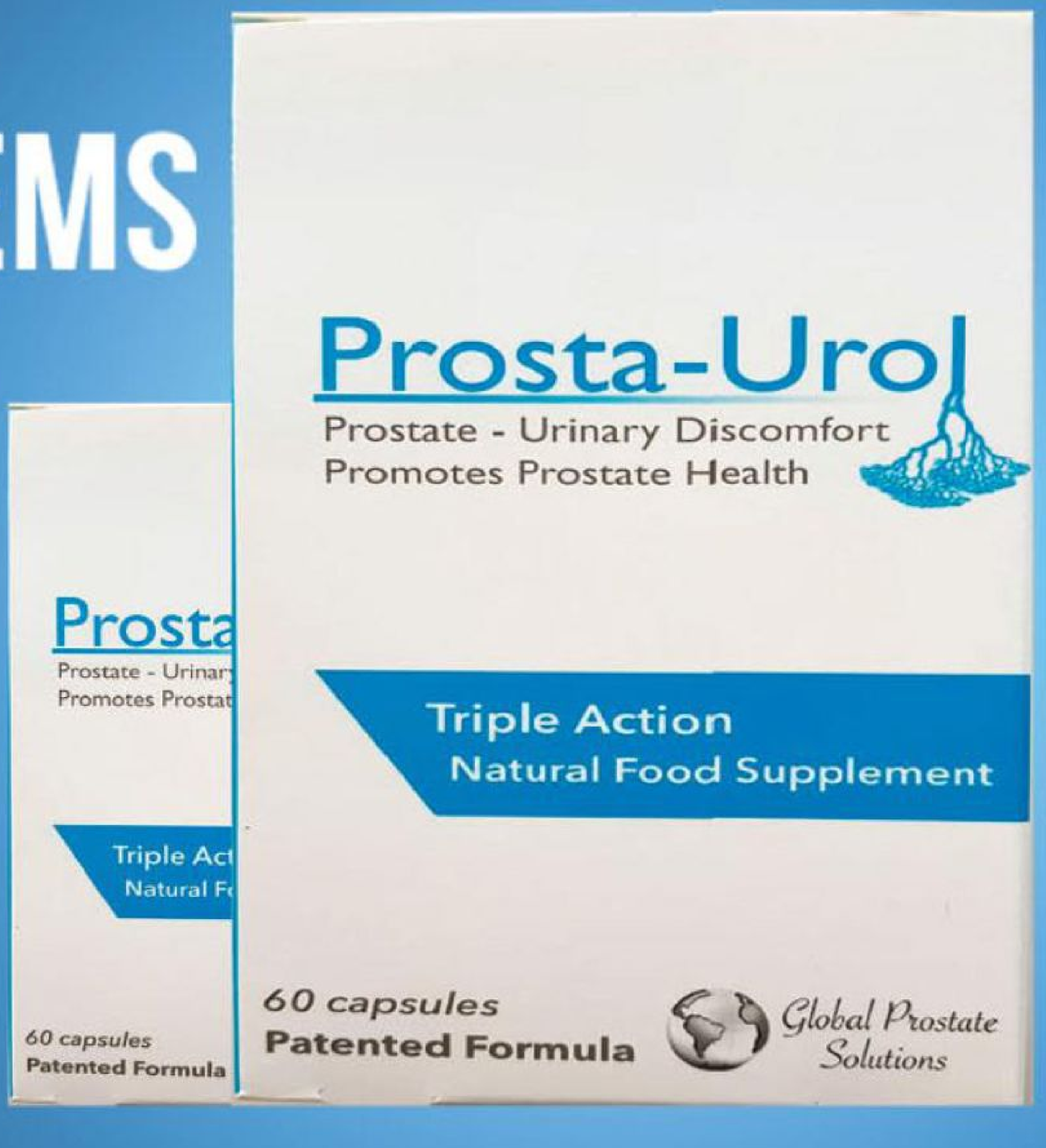

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SYNSCAN™ APP FEATURES

- SynScan™ App Database: Total 10,000+ Objects. Deep Sky Objects: 10759, including Messier, NGC, IC, Caldwell Catalogues, Named DSOs, Named Stars: 305, Double Stars: 55, Solar system objects: 7 planets, Sun, Moon. (Unlimited objects when working with a 3rd party planetarium software).
- SynScan™ App Alignment Method: Brightest Star Alignment, North-Level Alignment
- SynScan™ App's Other Features: Tonight's Best Sky Tour, Point and Go with a mobile device, Identification of Celestial Objects, Remote control over Internet, User defined objects, Pointing Accuracy Enhancement (PAE)

Wi-Fi

SYNSCAN™ GO-TO

AZ-GTe, AZ-GTi & STAR DISCOVERY Wi-Fi GO-TO TELESCOPES

These telescopes have been designed to be controlled wirelessly with your Smartphone or Tablet, using the free SynScan™ App for iOS or Android. The mounts create their very own Wi-Fi network, so the mount can be used anywhere, without any reliance on other Wi-Fi networks. After entering your coordinates into the App and following a simple alignment procedure, you are ready to explore the universe using the App's intuitive touchscreen menu. The SynScan™ App provides full computerised GO-TO control, allowing your telescope to be automatically slewed to any one of the objects in the App's extensive database of 10,000+ celestial objects. The AZ-GTi and Star Discovery mounts incorporate Freedom-Find™ dual-encoders, allowing them to be moved manually without losing their alignment or positional information. All models also compatible with optional Synscan™ Handset and Cable code 20948/20160.

MERCURY-707 (AZ-GTe)
70mm (2.75") F/10 Wi-Fi GO-TO REFRACTOR

SRP £329

SKYHAWK-1145PS (AZ-GTe)
114mm (4.5") F/4.4 Wi-Fi GO-TO PARABOLIC NEWTONIAN

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STARTRAVEL-102 (AZ-GTe)
102mm (4") F/4.9 Wi-Fi GO-TO REFRACTOR

SRP £379

Wi-Fi

SYNSCAN™ GO-TO

Wi-Fi

SYNSCAN™ GO-TO

FREEDOM FIND™

EXPLORER-130PS (AZ-GTi)
130mm (5.1") f/5 Wi-Fi GO-TO PARABOLIC NEWTONIAN

SRP £399

SKYMAX-102 (AZ-GTi)
102mm (4") f/12.7 Wi-Fi GO-TO MAKSUTOV-CASSEGRAIN

SRP £419

SKYMAX-127 (AZ-GTi)
127mm (5") f/11.8 Wi-Fi GO-TO MAKSUTOV-CASSEGRAIN

SRP £529

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STAR DISCOVERY 90i
90mm (3.5") f/10 Wi-Fi GO-TO REFRACTOR

SRP £419

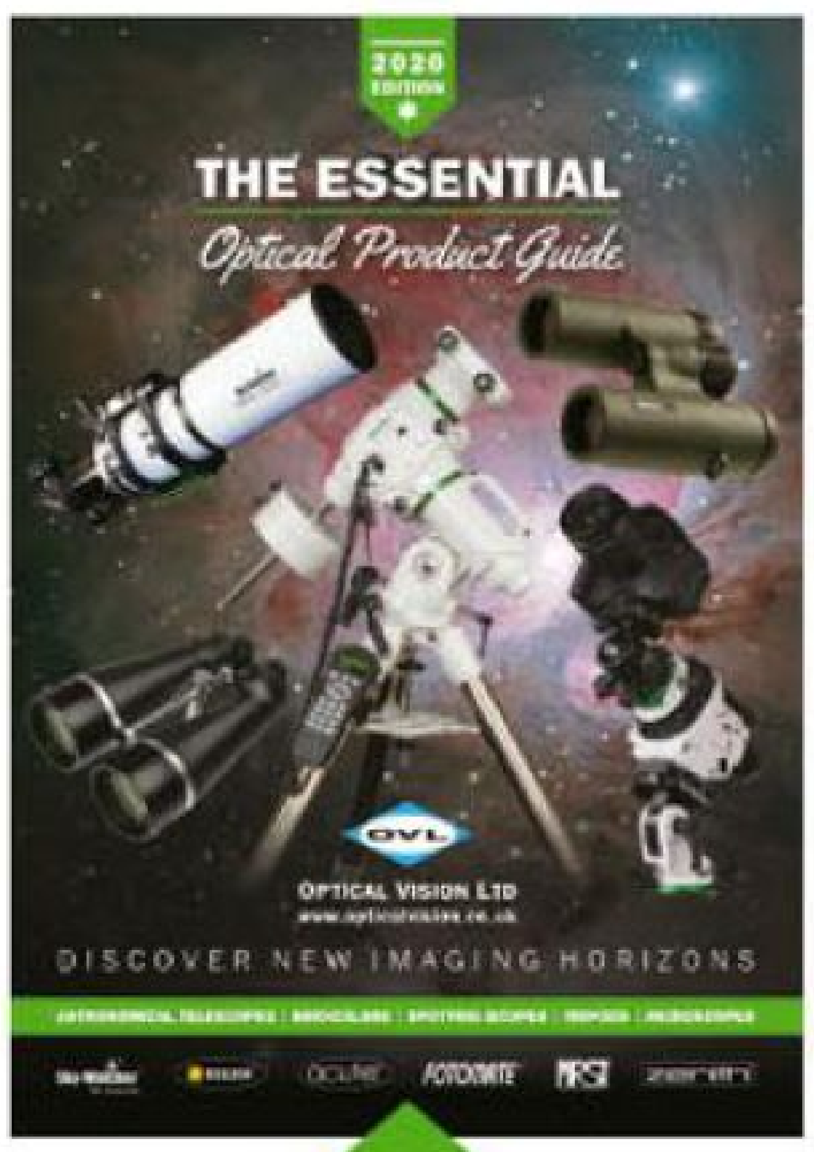
STAR DISCOVERY P150i
150mm (6") f/5 Wi-Fi GO-TO PARABOLIC NEWTONIAN

SRP £439

Wi-Fi

SYNSCAN™ GO-TO

FREEDOM FIND™



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